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Flooding Stress: Effect on Plants and Adaptive Mechanisms

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Introduction

The interaction of plants with the environment is a continuous process in which water plays a central role. At a global scale, indicators such as potential evapo transpiration and the number of wet days per year directly determine the distribution of plants and species richness in a geographical context. Agriculture around the world is constantly challenged by the rising incidence of adverse weather events as a consequence of global warming. Extreme events that alter water availability, like droughts and floods, constitute big threats to food security all damage and loss to crops with a value of billions of dollars

Classification

Based on the height of the water column produced, flooding can be classified as water logging, when it is superficial and covers only the root, or as submergence, when water completely covers the aerial plant tissues. Both types of flooding disrupt the movement of oxygen from the air to plant tissues, producing a natural condition known as hypoxia. At the agronomic level, there are different strategies there are different strategies to cope with submergence or water logging, such as developing standard models for the prediction and assessment of crop loss to floods for risk management, economic insurance, and decision making. Systems have been designed to predict flood-affected and flood destroyed crop areas based on correlations to standard climate indices or to estimate flooded crop acreage, crop damage and flood frequency and use algorithms to support post-flood crop loss estimation. These systems constitute useful tools for planning, managing and applying solutions for the mitigation of damage to crops caused by floods.

Molecular Sensing Of Less Oxygen, Metabolic Adjustments And Flooding Stress

Studies reported over 75 years ago first gleaned that cells of plant tissues (seeds, roots and aerial organs) surrounded by stagnant water undergo a shift from carbon-efficient aerobic respiration to carbon-inefficient anaerobic metabolism to produce sufficient ATP to maintain viability. The rate of anaerobic metabolism promoted by low O_2 or flooding stress can vary considerably, with some cells vigorously increasing flux through glycolysis (Pasteur effect) and others with more conservative carbohydrate consumption. Ahallmark of the onset of anaerobic metabolism in plant cells is increased transcription of genes and production of enzymes for ethanolic fermentation, namely pyruvate decarboxylase (PDC) and alcohol dehydrogenase (ADH), as reported in the first molecular characterization of the response to low O_2 in a plant. This can be accompanied with enhanced catabolism of carbohydrates such as starch to fuel fermentative metabolism and in some highly tolerant species even growth.

Root Architecture and Responses

Root architecture and plasticity play an important role in the adaptation to submergence and waterlogging stress. The formation of aerenchyma and adventitious roots is a morphological characteristic of waterlogging-tolerant species. Aerenchyma is known to enhance internal oxygen diffusion from the aerial parts to the waterlogged roots that allows the roots to maintain aerobic respiration. Two types of aerenchyma can be found in roots: primary aerenchyma, consisting of lysigenous aerenchyma, and schizogenous aerenchyma in the roots of rice, maize and wheat, and secondary aerenchyma in soybean roots. The formation of lysigenous aerenchyma results from the selective death and subsequent lysis of root cortical cells, while schizogenous aerenchyma formation is caused by cell separation, without the occurrence of cell death. Secondary aerenchyma develops from phellogen, forming spongy tissue filled with air spaces outside of the stem, hypocotyl, and roots.

Developing Tolerance to Flooding Stress

Sustained interdisciplinary research has resulted in breeding of submergence tolerant varieties , but additional knowledge and opportunities exist for further improvement of rice for various ecosystems and improvement of other crop and pasture species (e.g. wheat, maize, soybean, alfalfa/ lucerne, and others). Soil waterlogging leads to root-zone hypoxia/anoxia, high CO_2 and ethylene, and phytotoxins in reduced soils, with additional impacts also when shoots are submerged; also important is the ability to segue from inundation with water to a stagnant waterlogged or even waterlimited environment. Research is addressing the individual and interactive effects of these components of the 'compound stress' caused by flooding. The interest in roles of hormones, particularly ethylene and the

SnRK1 low-energy signaling pathway, as well as further consideration of wild species, is likely to provide fruitful insights. As flooding can co-occur with other stress factors (e.g. or phytotoxic metals), the elucidation of plant responses to situations of stress combinations is also underway. Multidisciplinary team approaches are likely to lead to the most rapid gains in knowledge of plant stress tolerance.

Conclusion

Scientific understanding of plants' responses to submergence and waterlogging has dynamically evolved from the pioneering works dealing with fermentative metabolic changes to current state of the art research creating a picture of interconnected perception, transduction and signaling events aimed to support the plant cell in the transit from stress up to the always expected recovery phase.