EFFECTS OF LOW WATER POTENTIAL ON GROWTH

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ABSTRACT

Plants responded physiologically and biochemically to water deficiency in many respects, such as inhibition of stem and root growth, inhibition of photosynthesis, changes in gene expression, and increase of ABA synthesis. Growth is the most obvious feature of plant activity because it causes plants to become larger or cells to become more numerous in a population. All the work of metabolism is directed toward it, and the ability to reproduce depends on it. Because we will define plant growth to be an irreversible increase in size to separate it from the reversible changes and water plays a large role in growth, water avaiability often becomes a problem. Understanding how growth is limited under these conditions can have many applications in agriculture and in the management of natural plant communities.

Much of our understanding of cell enlargement comes from studies of single cells of plants such as the large-celled algae *Nitella flexilis* and *Chara corallina*, because the cells of these species are large enough to observe easily, are in direct contact with the surrounding medium, and are photosynthetic and self-sufficient for substrate which simplifies growth experiments. Based on the previous findings, Lockhart (1965) formularized the concepts in an equation of the form:

$$G = m\,(\Psi_p - Y)$$

where G is the relative growth rate, Ψ_p is the turgor pressure (Mpa), Y is the yield threshold turgor (Mpa) and M is the wall extensibility. According to this equation, growth occurs more rapidly when Ψ_p increases.

However, when Green et al decreased Ψ_p in *Nitella* , elongation ceased and then resumed at the original rate. Ortega et al observed a similar behavior when Ψ_p was increased in single cells of fungus. These differences between theory and observation caused Zhu and Boyer to do additional experiments with *Chara* . By tinjecting cell solution thus changing turgor without changing osmotica in the external medium, they were able to repeat the results of Green et al and concluded that turgor had no other effect on growth rate. They also observed that growth was immediately inhibited without affecting the turgor when energy metabolism was inhibited, suggesting that

growth was highly dependent on metabolism.

Although there is a crutial difference between single cells and more complex plants many of the principles observed with single cells carry over to complex plants. To study the effects of water deficiency on growth our laboratory developed a dark-grown soybean seedling system, in which transplanting to low water potential vermiculite (-0.3 MPa) inhibited stem growth, while root growth was not affected. This stem growth inhibition is followed by the large solutes accumulation enough to maintain turgor at a value of controls by osmotic adjustment. This osmotic adjustment has been observed also in the growing regions of leaf, stem and root in maize.

The turgor maintenance and high solutes content for metabolic substrates during water deficiency suggested that growth inhibition might be achieved by factors other than turgor and substrates availability in dark-grown soybean seedlings. Cell wall extensibility may be involved in growth inhibition at low water potential. Nonami and Boyer (1990a, 1990b) reported that cell wall extensibility in stem growing region in soybean was decreased at low water potential. This decreased wall extensibility was also detected in maize growing leaves after addition of non-penetrating osmolyte polyetylene glycol 6000 to the root growth medium. However, it is not clear how mechenical properties of cell wall changed by water deficiency.

Change of metabolic processes, particularly affecting cell wall metabolism, may be involved in alteration of cell wall mechenical properties, which in turn affect growth. Bozarth et al (1987) found that the 28 kilodalton protein increased in the cell wall of growing region after soybean seedlings were subjected to water deficiency. Although this 28 kilodalton protein was named as vegetative storage protein based on the behavior of the protein in soybean leaves, this protein has found to have sequence homology with acid phosphatase in tomato and has shown to have acid phosphatase activity. Because this protein was localized in cytoplasm as well as in cell wall and has phosphatase activity, it would be interesting to see whether this protein is related with growth during water deficiency. Analysis of metabolic intermediates showed large amounts of glucose and fructose were accumulated but little sucrose. No differences were found in the levels of UDP-glucose, G-6-P, F-6-P, G-1-P, and 3-PGA except inorganic phosphate content which doubled in the growing region of water-deficient seedlings. We also observed increased cell wall content in the growing region. The increase of cell wall content in the growing region was not due to the increase in cell number, because the cell number was different only 4 %. The implication of increse of cell wall content in the growing region will be discussed.