How WATER Affects Plant Life

By S. R. WEST
Plant Physiologist
Crops Research Division, Agricultural Research Service
U. S. Department of Agriculture, Florida Agricultural Experiment Station
Gainesville, Florida

PLANT GROWTH and other biological systems are only possible because water possesses the most unusual combination of properties of any known liquid. Environmental extremes are tempered and reduced by these properties. Evaporation produces a strong cooling effect, and its condensation from vapor has a warming effect. It is a good conductor of heat, and thus water distributes heat received on a plant's surface rapidly throughout the plant itself. This conductivity also enables heat to be readily passed from inside the plant to its surfaces to help reduce damage during short periods of low temperatures.

The high density, high surface tension, and high tensile strength of water allow it to withstand the suction forces that pull it to the tops of plants. Water adheres firmly to plant surfaces, and its tendency to be absorbed explains why there are large amounts of water in cell walls and protoplasm; why they swell when they take in water.

Since it is a poor conductor of electricity, water is an excellent solvent for electrolytes, which can ionize freely. Another desirable property, of significance to green plants, is the high transparency of water that permits light and other forms of radiation to penetrate even thick leaves. But, because water is not transparent to infrared light, it traps heat inside the plant.

Uses Of Water In Plants

Because of its unique combination of properties, water is an essential factor to the very existence of life on earth. Water has the most unusual combination of functions of any substance found in plants. These functions can be listed under four general headings.

As a constituent. Water, an essential constituent of active protoplasm, often makes up 80-90% of the fresh weight of grass plants. A decrease in water content much below normal is accompanied by a decrease in rates of various physiological processes. If the water content falls below a certain critical value, death from dehydration occurs. A few plants can be dehydrated to air dryness without being killed, but most of our grasses do not fall into this category. Even when the water content is reduced to a low level by such treatment, physiological activity also is reduced to a low level. Water, therefore, is a very important constituent of protoplasm.

As a reagent in plant use. Various physiological processes in plants depend upon water as a reactant, including photosynthesis, the conversion of starch to sugar, and the breakdown of protein to amino acids. An important reagent in all of the ester formations that take place in plants, it is essential for many of the energy transfer reactions. Water can react with all kinds of compounds because of its unique chemical properties.

As a solvent. Water is perhaps the most universal solvent known. Even most gases are readily soluble in water. Thus, oxygen and carbon dioxide can readily pass from cell to cell within a plant. Vacuoles, or large central cavities in older cells filled with a water solution of many components, serve as a sump for toxins and other excess materials because of the great range of solubilities in water. Cells are joined together by water and permit transfer of soluble materials from one cell to another and from one organ to another. Many important substances such as sugars, organic acids, phosphates, and nitrates are soluble (if hydrogen bonding is possible) and therefore transferred.

For maintenance of turgor. Another role of water is to maintain turgor, essential to leaf form, new shoots, stems, and other plant structures. Water and turgor are essential to the opening of stomata (gas and vapor exchange pores) and movements of leaves, flower parts, and other plant structures controlled by changes in turgor. The most evident effect of an internal water shortage is a reduction in vegetative growth, because maintenance of a sufficiently high water content for a certain minimum turgor seems essential for cell enlargement.

Amount Of Water Used

Although plants actually use less than 5% of the water that passes through them, the total volume they take up appears to be necessary. The State Climatologist of the U. S. Weather Bureau of Gainesville, Florida, calculated that evapotranspiration of water from grass sod could be as high as 40 inches in a 12-month period. Thus, turf uses 3½ feet of water each year. Due to poor water-holding capacity of many Florida soils, poor distribution of rainfall, and too high use of water, deficits of water develop in our grasses, loss of turgidity occurs, numerous plant processes are impaired, growth is reduced or ceases, and death from desiccation finally results.

Survey Of The Problem

The best hope of relief would seem to be through the development or introduction of grasses that are better able to withstand the stress of drought. With this motivation, we have been attempting to locate and describe the metabolic processes in a grass plant that are affected by water stress. This information will provide plant breeders with specific selection criteria, so that their work can be greatly concentrated and a solution to the problem made more expeditious.

Research reported in the literature indicates that a variety of factors increase drought resistance. These include efficient root systems, thick cutin, and stomata that close promptly when water deficits develop. These characteristics serve to postpone the damage caused by drought; but the final test involves the ability of the living cell to endure critical water stress.

If we accept that cells are the fundamental units of which all living organisms are made, it may be assumed that the response of a plant to stress will be reflected by the effect of treatment on cellular processes. Cells grow as a result of the satisfactory completion of thousands of chemical reactions. Most of these reactions are mediated by enzymes which are made, to a large extent, from protein. Thus the expression of heredity or nuclear information must necessarily depend upon the proper synthesis of these proteins.

Proteins are giant molecules consisting of chains built from about 20 different kinds of amino acids or building blocks. Thousands of different proteins go into the makeup of one living cell. Those proteins perform thousands of different acts in the precise sequence that causes the cell to live. Each protein appears to be designed with high specificity for its particular task. The features of this design of proteins are the number and exact sequence of the amino acids that make up the large molecule.

The main task and function of genetic information is to provide that all of those proteins, that do the work of the cell, get synthesized in good order at the proper time. Genetic information of the cell which constitutes these instructions is embodied in another large molecule, deoxyribonucleic acid (DNA). DNA is largely confined to the nucleus and makes up a large portion of chromosomes. Protein synthesis takes place outside of the nucleus in the cytoplasm of the cell. Therefore, DNA does not take part directly in the aligning of amino acids to make proteins. Instead, the genetic code in the long double-chain molecule of DNA is transcribed into shorter single chains of ribonucleic acid (RNA) which carry away the information needed to construct one kind of protein. Because these molecules of RNA carry the genetic information, they are called messenger RNA (mRNA). Current dogma which is supported by data suggests that mRNA is made in the nucleus on DNA. The final joining of amino acids to make protein takes place on ribosomes which are found in the cytoplasm. These ribosome particles, visible only with the electron microscope, contain a large fraction of RNA.

Protein Synthesis Studied

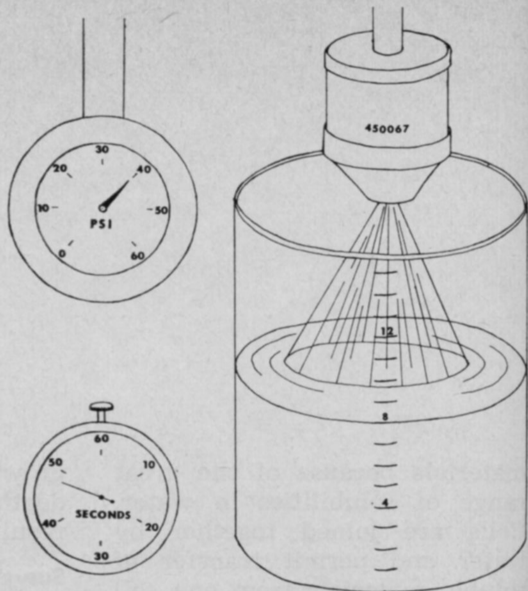
In our search for the key to what the stress of lack of water may be doing to limit growth, we looked first at protein synthesis. We found that when water stress reduced protein by 40%, growth was reduced twice that amount or 80%. Contrary to what may have been expected, total RNA increased by 30% in the same water-stress treatment. More surprising still, the increase in RNA appeared in the ribosome fraction. This meant more machinery was present for making protein, yet less was made.

Subsequent tests revealed that the information from the nucleus was being drastically altered by the water stress. We do not yet know whether messenger RNA is still being made as a result of the drought conditions, or whether the message that is synthesized does not contain the correct information. At any rate, we have determined that water stress prevents mRNA from functioning in protein synthesis. We are now trying to determine the nature of the effect of drought on this very important fraction of RNA. Then we will be searching for plant materials whose mRNAs are not susceptible to water stress, or for ways of inducing resistance in our fabricated, drought-tolerant grass.

References

1. Bernstein, L. The Needs and Uses of Water by Plants. USDA Yearbook of Agriculture, "Water" 18-25. 1955.
2. Kramer, P. J. Transpiration and the Water Economy of Plants. *Plant Physiology* edited by F. C. Steward Vol. II Academic Press N. Y. 607-726. 1959.
3. Meyers, B. S., Anderson, D. B., and Bohning, R. H. Introduction to Plant Physiology. D. Van Nostrand Co. Inc. N.J. 1960.
4. Parker, J. Drought Resistance in Woody Plants. Botan. Rev. 22: 241-289 (1956).
5. West, S. H., Protein, Nucleotide, and Ribonucleic Acid Metabolism in Corn During Germination Under Water Stress. Plant Physiology 37:565-571. 1962.

Are Worn Nozzles Stealing Your Spray Chemicals?



Worn and uncalibrated boom sprayer nozzles are important causes of wasted chemical on large-scale, blanket spray jobs. Holes in nozzles become larger from wear caused by impurities and abrasives in chemical sprays and water.

To determine the actual discharge of a spray nozzle, regulate the pump at 40 pounds per square inch (PSI), and catch the discharge of one nozzle in a measuring container for one minute. Use a container measured in ounces.

Check the number of the spray nozzle. Count three decimal places from the *left;* this will be the original discharge rate of the nozzle hole at 40 PSI. If, for example, the number is 8002, nozzle discharge should be 0.2 gallons per minute (GPM). If the number is 800067, the output from that nozzle should be .067 GPM.

Note the amount of liquid collected in the measuring container. When the nozzle output is supposed to be 0.2 GPM, 25.6 ounces should be collected. If .067 GPM is the nozzle-output rating, 8.5 ounces should be collected in one minute.

Ounces are converted to gallons by using the following formula:

$$\frac{128 \text{ oz.}}{1 \text{ gal.}} = \frac{\text{(Ounces collected in one min.)}}{\text{(Gallons discharged in one min., GPM)}}$$

If 8.5 oz. are collected, 8.5 replaces "(Ounces collected in one min.)" in the formula. To find "(Gallons discharged in one min., GPM)", cross-multiply.

$$\frac{128 \text{ oz.}}{1 \text{ gal.}} = \frac{8.5 \text{ oz.}}{\text{(Gallons discharged in one min., GPM)}}$$

$$1 \text{ gal.} \times 8.5 \text{ oz.} = 128 \text{ oz.} \times \text{(GPM)}$$

To find GPM, multiply 1 gal. by 8.5 oz. to get 8.5. Now divide by 128 and the answer is .067, showing that the nozzle is giving out the rated number of gallons it was originally calibrated to put out. However, if the nozzle number rating is less, .055 GPM for example, then the actual output (8.5 oz. or .067 GPM) is too much, and chemical spray will be wasted.

A nozzle that discharges .067 GPM when it is expected to discharge only .055 GPM wastes more than ½ gallon of spray solution in one 8-hour day. Multiply this waste (½ gallon) by the number of worn nozzles on a spray rig, 12 for example, and a total of 6 gallons of spray would be wasted each day.

Increased discharge by worn nozzles can be remedied in two ways. Either replace worn nozzle parts, or reduce the number of nozzles on the spray boom so the total discharge from all nozzles will not exceed recommended dosage rates.