

CROP WATER RELATIONS

Almost every plant process is affected directly or indirectly by the water supply. Decreasing water content is accompanied by loss of turgor and wilting, cessation of cell enlargement, closure of stomata, reduction in photosynthesis and interference with many basic metabolic processes. Eventually, continued dehydration causes disorganization of the protoplasm and death of most organisms.

7.1 PHYSIOLOGICAL IMPORTANCE OF WATER:

The importance of water can be summarized under the following general headings.

a) Constituent of Protoplasm

Water is important quantitatively and qualitatively, constituting 80 to 90 percent of the fresh weight of most herbaceous plant parts and over 50 percent of the fresh weight of woody plants. Water is important as a part of the protoplasm as the protein molecules which constitute the protoplasm framework, changes in structure if the water content is dropped below certain level. This ultimately leads to death of plants. It is true that a few plants and organs can be dehydrated to the air-dry condition or even to the oven-dry condition as in the case of some kinds of seeds and spores, without loss of viability, but a marked decrease in physiological activity always accompanies decrease in water content.

b) Solvent

A second essential function of water in plants is as the solvent in which gases, minerals and other solutes enter plant cell and move from cell to cell and organ to organ. The permeability of most cell walls and membranes to water in a continuous liquid phase extending throughout the plant in which translocation of solutes of all kinds occurs.

c) Reagent

Water is a reactant or reagent in many important processes, including photosynthesis and hydrolytic process such as the hydrolysis of starch to sugar. It is also essential for fixation of carbon dioxide or nitrate.

d) Maintenance of Turgidity

Another essential role of water is the maintenance of the turgidity which is essential for cell enlargement and growth, and for maintaining the form of herbaceous plants. Turgor is also important in the opening of stomata and the movements of leaves, flower petals and various specialized plant structures. Inadequate water to maintain turgor results in an immediate reduction of vegetation growth.

7.2 WATER POTENTIAL AND ITS COMPONENTS:

Water potential or chemical potential of water is a quantitative expression of the free energy associated with water.

Water potential is symbolized by the Greek letter Ψ (psi) and is defined relative to the water potential of pure water, which is zero. Hence the value of Ψ is always negative. The units of water potential are mega Pascal (MPa). It is a relative quantity and depends on concentration, pressure and gravity at the same temperature.

Water potential as the sum of component potentials which may be written as

$$\Psi = \Psi_s + \Psi_m + \Psi_p + \Psi_g$$

Where Ψ_s = Solute or osmotic potential (symbol π)

Ψ_m = Matric potential (Symbol T)

Ψ_p = Pressure potential (Symbol P)

Ψ_g = Gravitational potential (Symbol G)

Osmotic potential

The osmotic potential, Ψ_s (or π) is the component produced by solutes dissolved in the cell sap, chiefly vacuolar sap.

Matric Potential

The matric potential, Ψ_m (or T) refers to water held in micro capillaries or bound on surfaces of the cell walls and other cell components.

Pressure potential

The pressure potential Ψ_p (or P) is the turgor pressure produced by diffusion of water into protoplasts enclosed in walls which resist expansion. In the xylem of transpiring plants Ψ_p is usually negative and in guttating plants it is positive as a result of root pressure.

Gravitational Potential

The effect of gravity, Ψ_g (or G) is a term of negligible importance within root or a leaf but becomes important in comparing potentials in leaves at different heights on trees and in soils.

Upward movement of water in a tree trunk must overcome a gravitational force of 0.01 Mpa/m and gravity causes drainage of water downward in soil.

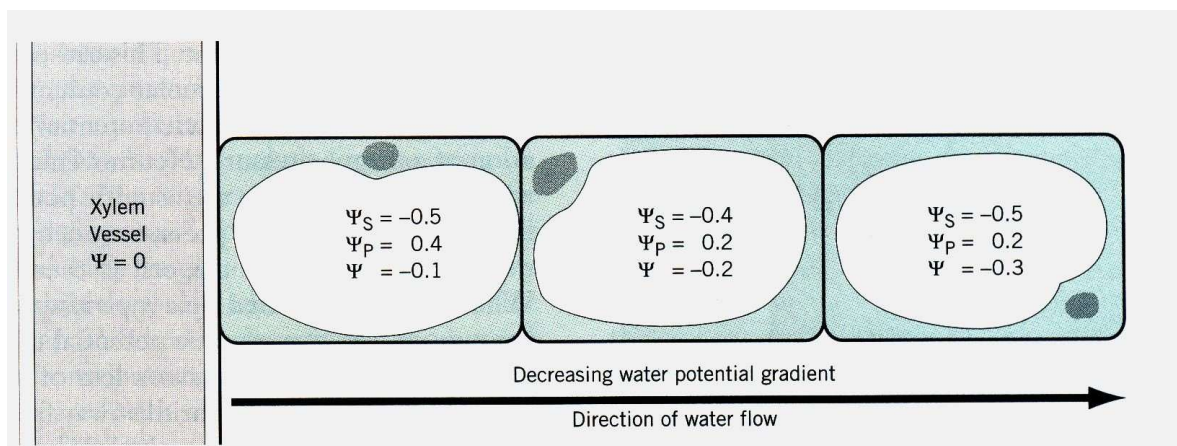
The volume of matric water is very small compared the volume of vacuolar water in parenchyma, therefore Ψ_m has a negligible effect on the total water potential Ψ . However, in developing seeds or thick walled cells where the vacuolar

water constitutes a small fraction of the total water, matric potential can control the cell water potential.

Thus for herbaceous plants and annual field crops of a short vertical height (less than 10 m) the values of the matric potential and gravitational potential are small and are commonly omitted. Thus

$$\Psi = \Psi_s + \Psi_p \text{ or } P - \pi$$

Water always moves from less negative water potential to more negative water potential.(Figure.4)



*Figure.4 is from reference 5

7.3 IMPORTANCE OF WATER POTENTIAL:

Water potential is a diagnostic tool that enables the plant scientist to assign a precise value to the water status in plant cells and tissues.

The lower the water potential in a plant cell or tissue, the greater is its ability to absorb water. Conversely, the higher the water potential, the greater is the ability of the tissue to supply water to other more desiccated cells and tissues.

Thus water potential is used to measure water deficit and water stress in plant cells and tissues.

As a general rule, leaves of most plants rooted in well watered soils are likely to have water potentials between about -2 and -8 bars. With decreasing soil moisture supply, leaf water potential will become more negative than -8 bars and leaf growth rates will decline. Most plant tissues will cease growth completely (i.e., will not enlarge) when water potential drops to about -15bars.

7.4 UPTAKE OF WATER

The way in which water is entered in to the root hair and the precise mechanism of water absorption is has been explained by two different approaches.

(a) Active uptake:

Water is absorbed as a result of activities in the root itself and does not concern with any process in shoot.

(b) Passive uptake of water:

The governing force of water absorption originates in the cells of transpiring shoots rather than in root itself.

Although the absorption of water by roots is believed to be a passive, pressure driven process, it is nonetheless dependent on respiration. Respiratory inhibitors (such as cyanide), anaerobic conditions (waterlogged condition) decrease in the hydraulic conductance of most roots. These are some supporting points for active absorption of water. However the exact role of respiration and active uptake is not clear.

Barring few exceptions, it is now believed that uptake of water is a Passive process. Tension or negative pressure originating at the actively transpiring leaf surface creates a pulling force for water movement in xylem. (Cohesion-tension theory of Dixon and Jolly)

The movement of water inside the plant is driven by a reduction in free energy, and water may move by diffusion, by bulk flow or by a combination of these fundamental transport mechanisms. Water diffuses because molecules are in a constant thermal agitation, which tends to even out concentration differences. Water moves by bulk flow in response to a pressure difference, whenever there is a suitable pathway for bulk movement of water. Thus, water potential difference (i.e. solute potential and pressure potential) across the cells starting from root hairs to xylem plays an important role in uptake and transport of water.

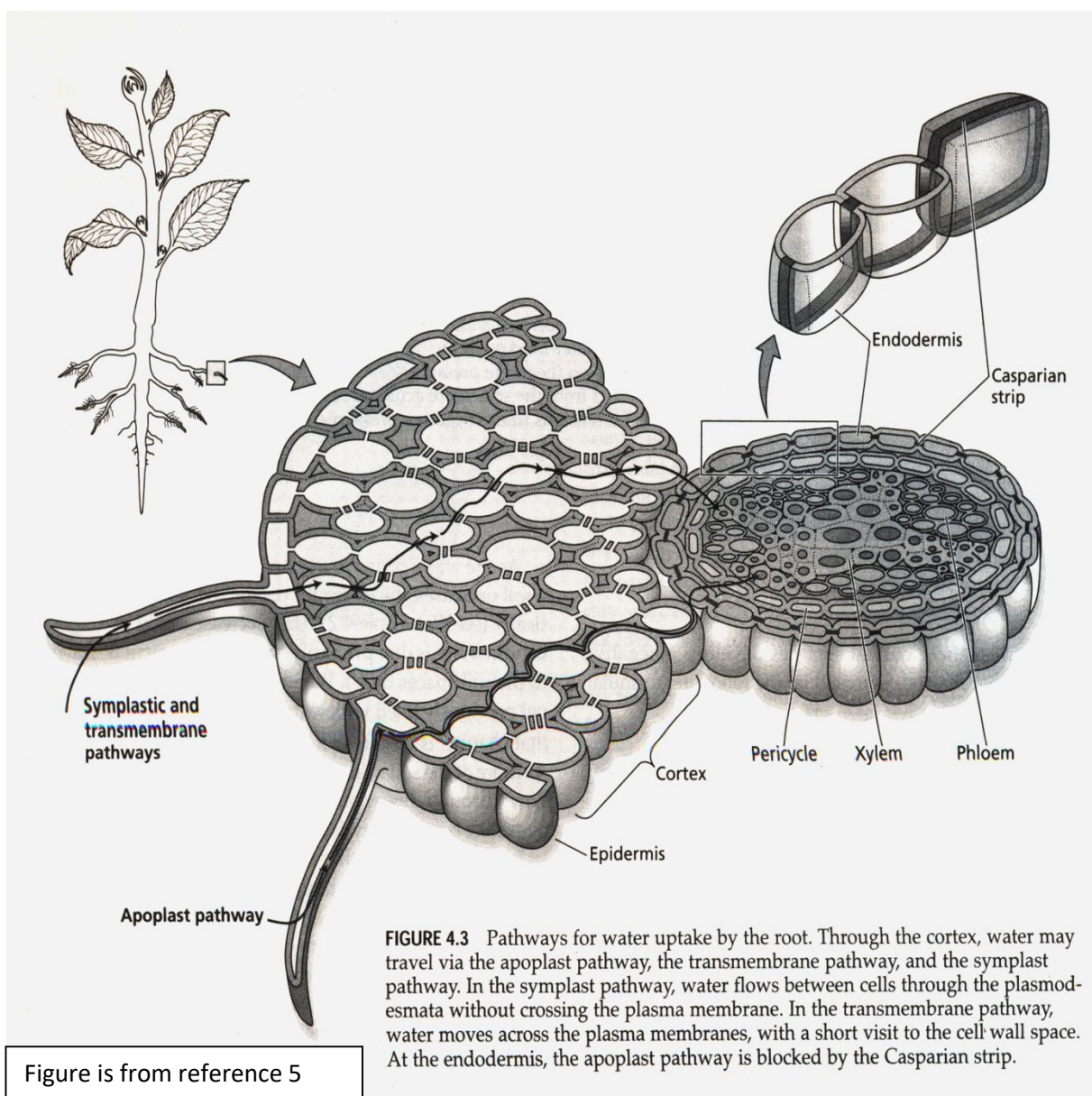


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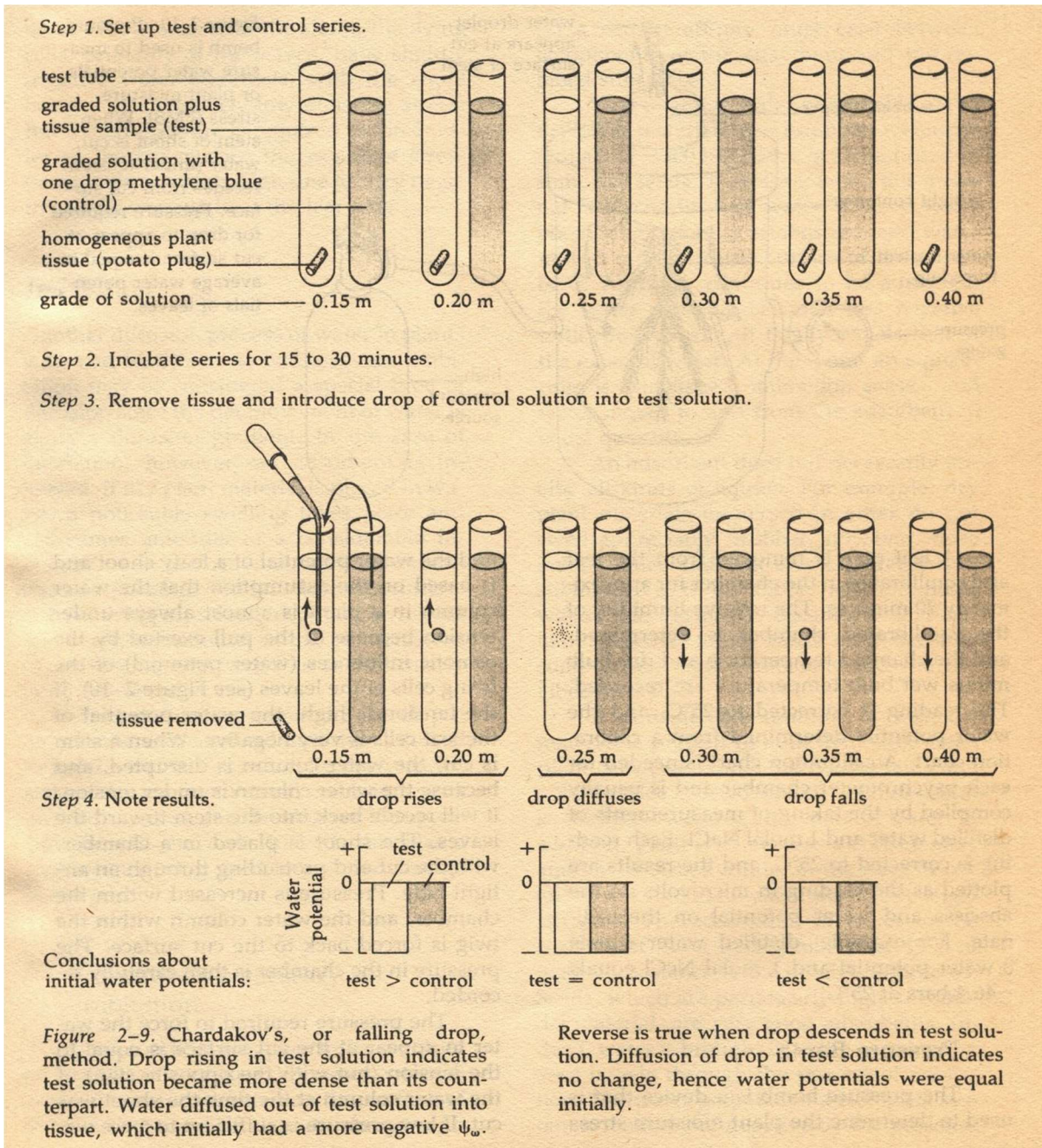
7.5 METHODS OF MEASURING WATER STATUS IN PLANTS:

There are two general ways to describe the water status or internal water balance of plant and plant tissue. The first one is based on the energy associated with water in the plant tissue. Water potential is considered by most plant physiologists to be the most useful and significant way to describe the water status of plant tissues. In terms of water potential, water deficit exists in a tissue when ever its water potential is less i.e., more negative than zero mega Pascal (Mpa). The water potential is measured by (1) liquid immersion method (dye method) (2)vapor equilibration method (Thermocouple Psychrometer) and (3)pressure chamber method.

7.5.1 Liquid immersion method or dye method or Chardakov's Falling Drop Method

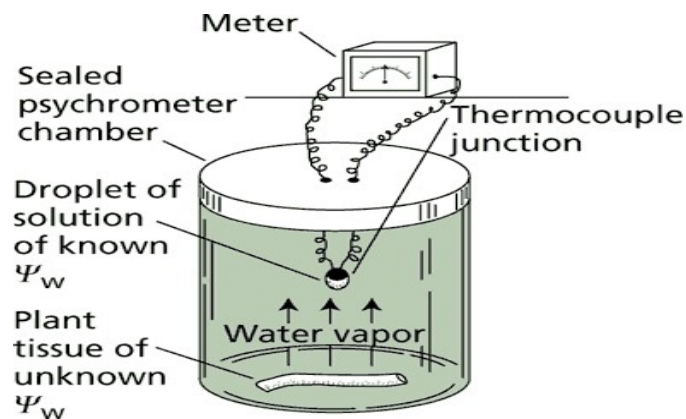
Tow graded series of sucrose solutions (ranging from 0.15 to 0.50 molal in increments of 0.5molality) are placed in test tubes set up in duplicate. Homogeneous plant tissue is placed into each test tube of one of the series (test series). Only a drop of methylene blue is mixed into each solution of the second series (control series) Plant tissue is not added to the control series and the dye does not appreciably change the osmotic potentials.

After the tissue is incubated for 15 to 30 minutes, It is removed from each tube. The actual time of incubation can be just long enough for osmosis to proceed and change the concentration of each solution in the test series; the attainment of equilibrium is not necessary. After the tissue is removed, a small drop of the respective control series solutions is introduced below the surface of its corresponding test solution. If the drop rises in the test solution, it means that the drop is lighter and that the tissue incubation solution is more concentrated – an indication that water from the solution entered the tissue. Conversely, if the drop falls, it means that the test solution is lighter-an indication that water has left the tissue and diluted the solution. In this latter instance, the water potential of the solution initially is more negative than that of the tissue. Accordingly, if the density of the drop from the methylene blue solution is the same as that of the test solution, the drop will diffuse into the solution uniformly. At this point (called the null point), the water potential of the tissue and solution is equal.



7.5.2 Vapour equilibration (Thermocouple Psychrometer) Method

Psychrometry (the prefix "psychro-" comes from the Greek word *psychein*, "to cool") is based on the fact that the vapor pressure of water is lowered as its water potential is reduced. Psychrometers measure the water vapor pressure of a solution or plant sample, on the basis of the principle that evaporation of water from a surface cools the surface.



Investigators make a measurement by placing a piece of tissue sealed inside a small chamber that contains a temperature sensor (in this case, a thermocouple) in contact with a small droplet of a standard solution of known solute concentration (known Ψ_s and thus known Ψ_w). If the tissue has a lower water potential than that of the droplet, water evaporates from the droplet, diffuses through the air, and is absorbed by the tissue. This slight evaporation of water cools the drop. The larger the difference in water potential between the tissue and the droplet, the higher the rate of water transfer and hence the cooler the droplet. If the standard solution has a lower water potential than that of the sample to be measured, water will diffuse from the tissue to the droplet, causing warming of the droplet. Measuring the change in temperature of the droplet for several solutions of known Ψ_w makes it possible to calculate the water potential of a solution for which the net movement of water between the droplet and the tissue would be zero signifying that the droplet and the tissue have the same water potential.

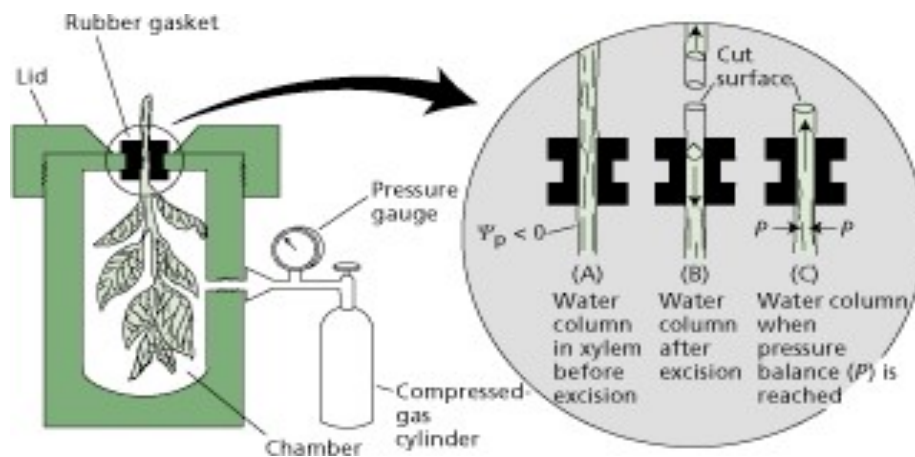
Psychrometers can be used to measure the water potentials of both excised and intact plant tissue. Moreover, the method can be used to measure the Ψ_s of solutions. This can be particularly useful with plant tissues.

A major difficulty with this approach is the extreme sensitivity of the measurement to temperature fluctuations. For example, a change in temperature of 0.01°C corresponds to a change in water potential of about 0.1 MPa. Thus, psychrometers must be operated under constant temperature conditions. For this reason, the method is used primarily in laboratory settings.

7.5.3 Pressure chamber method

A relatively quick method for estimating the water potential of large pieces of tissues, such as leaves and small shoots, is by use of the **pressure chamber**. This method was popularized by **P. Scholander** and coworkers. The pressure bomb is a device that is used to determine the plant moisture stress and the water potential of a leafy shoot and is based on the assumption that the water column in a plant is almost always under tension because of the pull exerted by the osmotic influences (water potential) of the living cells of the leaves. If the tension is high, the water potential of the leaf cells is very negative. When a stem is cut, the water column (in xylem) is disrupted and because the water column is under tension, it will recede back into the stem toward the leaves. The shoot is placed in a chamber, with the cut end protruding through an airtight hole. Pressure is increased within the chamber and the water column within the twig are forced back to the cut surface. The pressure in the chamber is then carefully recorded.

The pressure required to force the water to appear at the cut surface is equal to the tension (but with the opposite sign) of the water column at the time the shoot was cut. If low pressure is sufficient to force water to the cut surface of the shoot, the shoot is under relatively low moisture stress. But if high pressure is required to force to the cut surface the moisture stress (tension) is relatively high due to very negative water potential of the leaf cells.



7.5.2 The second way to describe water status is to measure the quantity of water in a tissue i.e. its water content and to express it in relation to a selected references. Three of these methods are

- fresh weight method
- dry weight method and
- relative water content (RWC) method.
