

CROP WATER RELATIONS

8.1 TRANSPIRATION:

The loss of water from aerial parts of plants in the form of vapor is known as transpiration. The loose arrangement of the living thin walled mesophyll cells, which results in an abundance of inter cellular space provides an ideal condition for the evaporation of water from internal leaf surface. Part of the epidermal surface of the leaf is made up of a great number of microscopic pores called stomata. Water vapor collected in the intercellular spaces of leaf mesophyll diffuse into the atmosphere through the open stomata. This form of transpiration is termed as **stomatal transpiration**.

In addition to stomatal transpiration, water is lost as vapor directly from leaf surfaces and through lenticels (small opening in the corky tissue covering stems and twigs). The former is called cuticular transpiration and the later lenticular transpiration.

Stomatal Transpiration

The stomatal transpiration accounts to 80 to 98% of the total transpiration loss from plants (tree to herbaceous plants). Under very dry conditions, stomata are closed and water loss occurs through the cuticle and lenticels.

Cuticular Transpiration

The cuticular transpiration accounts to 2 to 20% of the total transpiration loss from plant (xerophytes to mesophytes). The cuticle although retards water loss, is some what permeable to water vapor. In plants with thick cuticles, this form of transpiration is insignificant.

Lenticular Transpiration

The lenticular transpiration amount to 0.1 to 1% of the total transpiration loss from plants which is insignificant when compared to stomatal transpiration. However, lenticular transpiration may cause some desiccation in those trees that shed their leaves at the on set of the winter. During cold winter water absorption by roots is at a minimum, thus the importance of lenticular transpiration is increased.

8.2 SIGNIFICANCE OF TRANSPIRATION

Transpiration is advantageous because.

- It creates suction force and help in the ascent of sap.
- It helps in the absorption of water and minerals by roots.
- It helps in evaporating excess amount of water from moist soil.
- It plays a role in translocation of food from one part of the plant to the other.
- It brings opening and closure of stomata which indirectly influences the gaseous exchange for the processes of photosynthesis and respiration.

- It helps in dissipating the excess energy absorbed from the sun, which will otherwise raise the leaf temperature.
- It maintains suitable temperature of leaves by imparting a cooling effect.

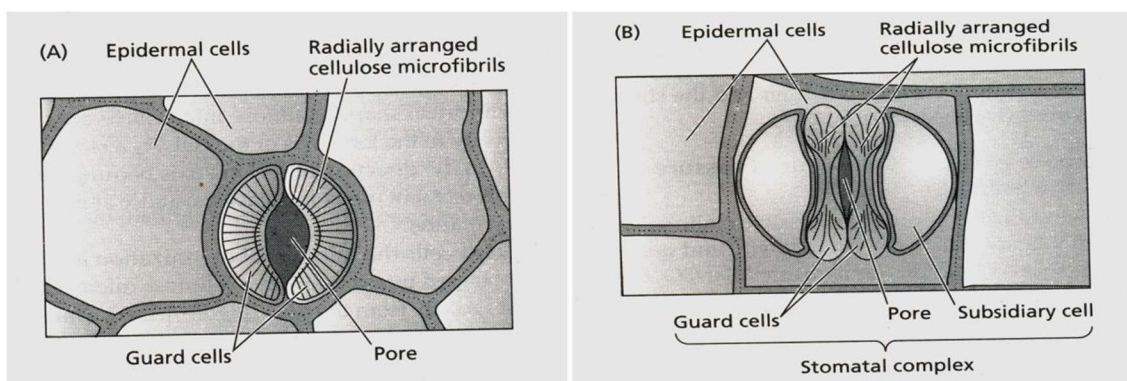
Transpiration is regarded as an unavoidable (necessary) evil. It is unavoidable because leaf structure (stomata) favorable for uptake of CO_2 and O_2 necessary for photosynthesis and respiration is also favorable for the loss of water through transpiration.

Transpiration is an 'evil' because often it causes injury by dehydration due to heavy transpiration loss when the atmospheric conditions are aggressive such as high light intensity, hot winds, depleted soil moisture and poor water retentive capacity of soil.

8.4 STRUCTURE OF STOMATAL COMPLEX IN MONOCOT AND DICOT SPECIES

The appearance of the guard cells differs characteristically from the surrounding epidermal cells. The guard cells of some plant species, particularly grasses (monocots), are **dumbbell shaped** and are associated with epidermal cells that also differ in appearance from the rest of the epidermal cells. These epidermal cells are called subsidiary cells or accessory cells. In case of dicots, the guard cells are generally **bean shaped**. (Fig.5)

One other distinguishing feature of guard cell is the presence of chloroplasts. Epidermal cells do not possess chloroplasts.



*Figure.5 is from reference 6

8.4.1 INVOLVEMENT OF STOMATA IN TRANSPIRATION :

The stomatal movement is generally understood as a direct response to increase or decrease in the osmotic potential that result from osmotic changes that cause water to move in or out of the guard cells. If water moves in, the cells expand (become **turgid**); if water moves out, they go **flaccid**. When the guard cells are turgid, the stoma is open; when the guard cells are flaccid, the stoma is closed. To effect this movement of water, an exchange must takes place between the guard

cells and the surrounding mesophyll and epidermal cells. The development of a **more negative osmotic potential** in the guard cells would cause of water potential gradient to develop between the guard cells and their neighboring cells. Water would diffuse in to the guard cell, causing them to become more turgid. The development of a **less negative osmotic potential** in the guard cells would of course, cause a water potential gradient to develop in the opposite direction, and water would flow out of the guard cells into the neighboring cells. (see the diagram in the annexure)

8.5 TRANSPIRATION IN RELATION TO PRODUCTIVITY:

The importance of water use efficiency (WUE) in influencing grain yield under water limited conditions can be explained by the following model give by passioura.

$$\text{Grain Yield} = T \times TE \times HI$$

Where T = Total transpiration by the crop canopy

TE = Transpiration Efficiency or WUE

HI = Harvest Index (Economic Fraction of Dry matter)

This relationship provides an analytical tool to select the genotype with high levels of T and TE.

8.6 WATER USE EFFICIENCY:

The water use efficiency (WUE) of field crops is defined as follows:

‘It is the amount of dry matter produced per unit amount of water transpired’

$$\text{WUE} = \frac{\text{Dry matter production (DM)}}{\text{Evapotranspiration}}$$

This is expressed as g DM kg⁻¹ water WUE measurements can be made on plants in containers, on individual plants, and on crop communities. They can be used for economic yield as well as total dry matter calculations.

A related term, **water requirement** is the reciprocal of WUE. Water requirements is usually expressed in weights of equal magnitude, such as g water (g DM)⁻¹

8.7 Water use efficiency in C₃ & C₄ plants.

Field data for WUE, when regrouped into C₃ and C₄ species, illustrate a two fold increase for C₄ species when calculated for either grasses or dicots

Water use Efficiency (g DM (kgH₂O)⁻¹) for C₄ and C₃ species.

Species	Grasses	Dicots
C ₃	1.49	1.59
C ₄	3.14	3.44

Large differences in WUE occur when species are categorized by Co₂ fixation pathway. It is now accepted that the WUE of C₄ species is generally higher than C₃ species. The higher WUE of C₄ species is a result of higher photosynthetic rate under high light and temperature and lower transpiration rates under low light.

The WUE values for both C3 and C4 species are low compared with CAM plants. One CAM species, pineapple (*Ananas comosis*), has shown a WUE of 20g, DM kg⁻¹ water. Use of crop species with CAM is limited because the Co₂ fixation and overall productivity of CAM plants is low (CAM is only a survival mechanism but not a productive mechanism).

8.8 WUE of major field crops :

Crop	Co ₂ Fixation pathway	water requirement (gH ₂ O, gDM ⁻¹)	water Use Efficiency (g DM kg ⁻¹ H ₂ O)
Maize	C ₄	388	2.58
Sorghum	C ₄	402	2.49
Potato	C ₃	532	1.88
Sugar beet	C ₃	606	1.65
Wheat	C ₃	613	1.63
Soybean	C ₃	704	1.42
Alfalfa	C ₃	993	1.01

8.9 FACTORS INFLUENCING THE WATER USE EFFICIENCY:

1. Climatic factors

WUE has almost an inverse relationship with Relative humidity (R.H), lower R.H. increases evapotranspiration (ET) without a corresponding increase in crop yield. On the other hand, factors such as sunlight and temperature that affect ET, rate of photosynthesis and dry matter production will either decrease or increase WUE.

2. Agronomic practices and crop management

Early sown crops will escape the moisture stress while the delayed sowing favors heavy weed growth which creates severe competition for water, light, nutrients etc. the crop should have an optimum crop canopy (4-6 LAI for most crops) for proper light interception. Plant Population and plant architecture influence WUE by influencing the interception and utilization of solar energy. Depth of sowing also influences water availability and there by seedling emergence, vigor and final yield.

3. Antitranspirants

WUE can also be improved by using antitranspirants which reduces transpiration. These antitranspirant may influence stomatal closure (Phenyl mercuric acetate, ABA, CCC Salicylic acid etc) or form a film (Hexadecanol, cetyl alcohol etc.) on the leaf surface or increase plant reflectivity (eg. Kaolinite) and reduce leaf temperatures.

4. Use of mulches

Mulches are beneficial in conserving or economizing water use by plant ranging from 10-50%. It depends upon the crop in which it is used, rainfall, wind velocity and temperature of both air and soil. Organic mulches (straw, rice dust, saw dust etc.) light colored and light reflecting mulches reduce soil temperature. But black colored mulches such as black, grey, transparent polythene sheets and petroleum products increase temperature up to 5-8⁰C. Plastic mulches are costly and suitable to areas where soil temperatures are low and unfavorable to crop growth.

5. Use of shelter belts

Shelter belts decrease the damaging effects of winds on crops and modify the micro climate. Higher humidity and lower vapor pressure deficit prevail in shelter belt that reduces heat. This will help ultimately for higher WUE. Increased yields due to shelter belts are reported in case of cotton, onion, sweet potato, tomato and wheat.

6. Method and quantities of water application.

Frequent light irrigations keep the soil surface wet for a longer period but consequently greater loss due to evaporation. Heavy application of water causes heavy deep percolation losses.

Selection of proper method of irrigation is important based on soil and crop characteristics. WUE is generally higher with sprinkler irrigation than surface method of irrigation. Drip irrigation also increases production and decrease the water use by a crop.

Among surface irrigation methods, WUE of crops increases in the order of wild flooding, border strip, check basin, basin and furrow irrigation.

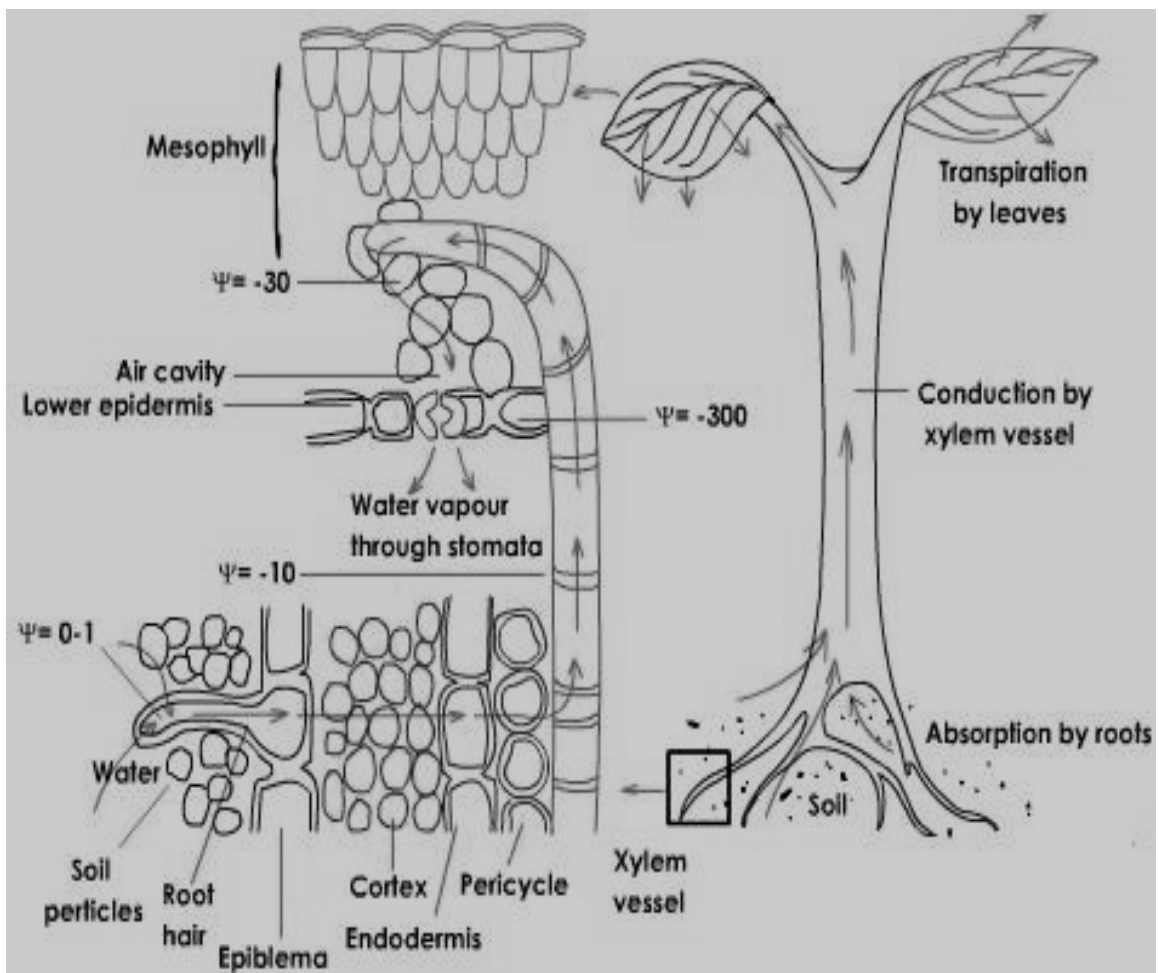
7. Fertilizer application

WUE of crops invariably increases with the application of fertilizers on deficient soils under adequate soil moisture conditions. This is particularly with high yielding varieties and hybrids.

8. Weed control

Weeds due to their early establishment and a better root system are able to exhaust soil moisture more effectively than crop plants. Therefore, both yield and WUE are reduced. Controlling weeds is essential for higher WUE of crops.

ANNEXURE



Movement of water towards more negative water potential