



WATER RELATIONS IN SEEDS

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INTRODUCTION

Seed /water relations basically refer to activities directed to life continuity and survival of plant species.

- **Seed development**
- **Quiescence**
- **Germination**
- **Desiccation tolerance**
- **Deterioration**

In this sense, physiological processes of synthesis, hydrolysis, energy liberation as well as those that occur in almost dehydrated seed tissues are involved.



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FUNCTIONS OF WATER IN SEEDS

- **Main constituent of living plant cells**
- **Represents 70% of the protoplasm weight of metabolically active cells**
- **Organization of cellular structure**
- **Organization and integrity of membranes**
- **Percentage, speed and uniformity of germination**
- **Rate and speed of seed deterioration**
- **Activity of insects and microorganisms**
- **Decisions at harvest time, seed drying, processing and storage**



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SEED WATER OR MOISTURE CONTENT

Seed water content (fresh weight basis) : percentage mass fraction of water of total seed mass

$$M.C.(\% Fwb) = \frac{Fw - Dw}{Fw} \times 100$$

Seed water content (dry weight basis) : mass ratio between water and the dry mass in seed tissues (gg^{-1} dw)

$$M.C.(Dwb) = \frac{Fw - Dw}{Dw}$$



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SEED WATER OR MOISTURE CONTENT

- Conversion of M.C. Fwb to Dwb

$$M.C.(Dwb) = \frac{M.C.(Fwb)}{100 - M.C.(Fwb)} \quad (\text{Equ.1})$$

- Conversion of M.C. Dwb to Fwb

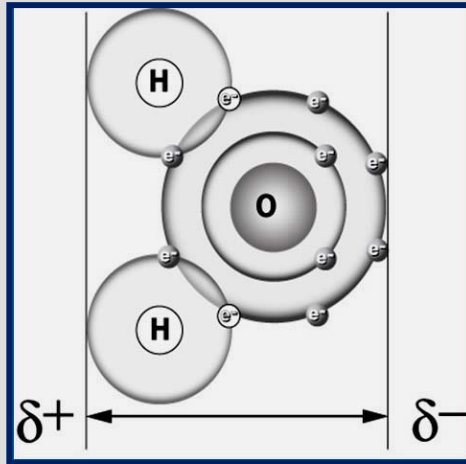
$$M.C.(Fwb) = \frac{M.C.(Dwb)}{100 + M.C.(Dwb)} \quad (\text{Equ.2})$$



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PROPERTIES OF WATER

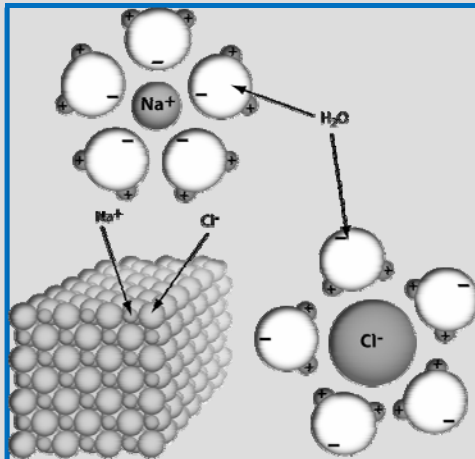
- Water composition and structure



The water molecule showing two electrons in the first shell and six electrons in the outer shell. Note that hydrogen shares its single electron with oxygen forming a covalent bond. Since oxygen is a larger atom than hydrogen, the electrons are pulled more to oxygen and away from hydrogen giving oxygen a net negative charge and hydrogen a net positive charge. This is referred to as a permanent dipole (graphic courtesy of the Agronomy Distance M.Sc. Program, Iowa State University).

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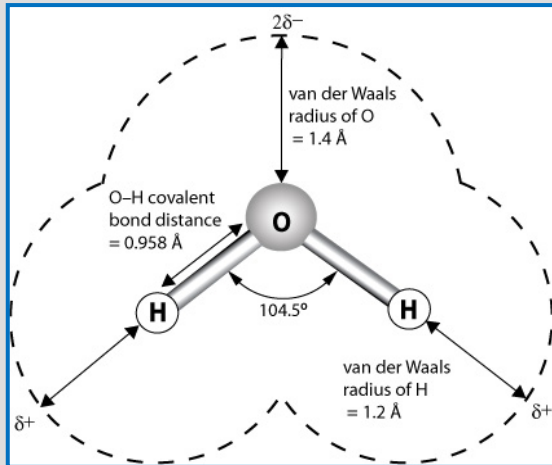
PROPERTIES OF WATER



An example of the affinity of water for a salt such as sodium chloride. Note how the negative oxygen of water surrounds the positive sodium ion and the positive hydrogens of water surround the negative chlorine ion (graphic courtesy of the Agronomy Distance M.Sc. Program, Iowa State University).

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PROPERTIES OF WATER



van der Waals forces are the distance that molecules possessing permanent dipoles are attracted to each other. In this example, this distance would be the attraction water has on the positive end of one molecule to the negative end of another molecule by a force called "hydrogen bonding" (graphic courtesy of the Agronomy Distance M.Sc. Program, Iowa State University).

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PROPERTIES OF WATER

Water composition and structure

- Bound water
- Chemical composition and affinity to water

Proteins

Starch

Lipids



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SEED HYGROSCOPIC EQUILIBRIUM

- **Hygroscopicity**
- **Air water holding capacity**

Temperature (°C)	Saturation Humidity (g water vapor / kg dry air)
0	3.8
10	7.6
20	14.8
30	26.4



Influence of temperature on air saturation humidity
(Harrington, 1972).

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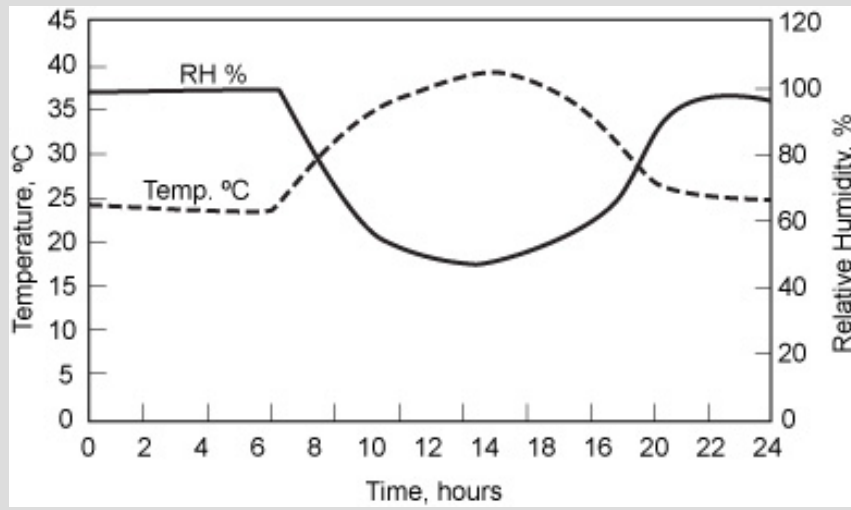
SEED HYGROSCOPIC EQUILIBRIUM

- **Relative humidity**
- **Atmospheric pressure**
- **Vapor pressure exchange and seed water content**
- **Hygroscopic equilibrium**

**Chemical composition, relative humidity, temperature,
permeability of seed coats, physical integrity**



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Typical changes in temperature and percentage relative humidity during a day. Note that high temperatures reduce percentage relative humidity while low temperatures increase percentage relative humidity (graphic courtesy of the Agronomy Distance M.Sc. Program, Iowa State University).

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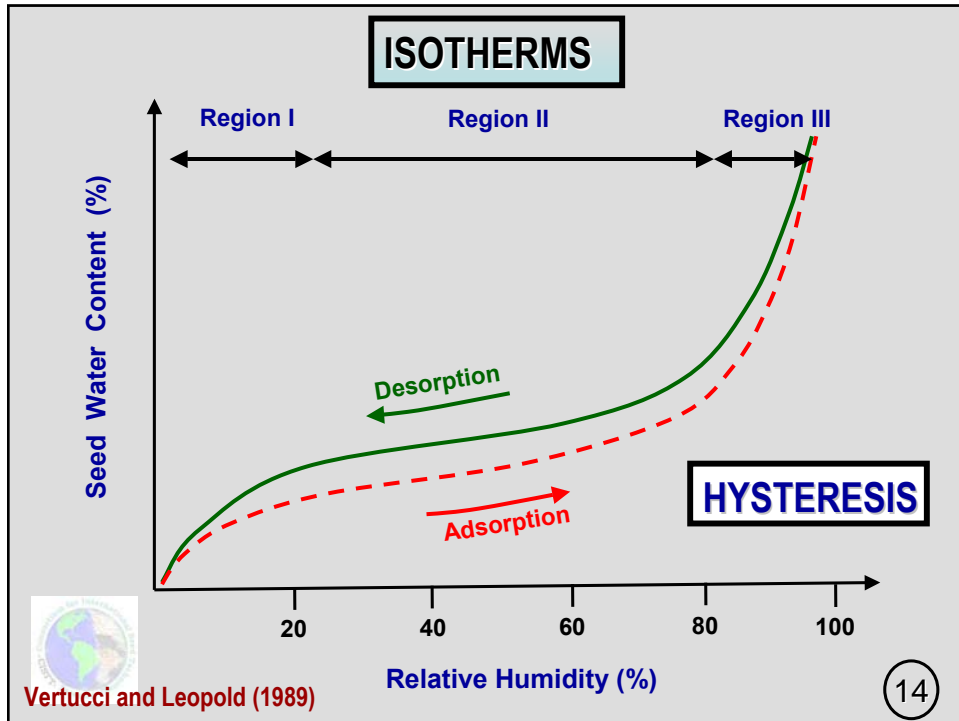
SEED HYGROSCOPIC EQUILIBRIUM

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- Atmosphere vapor pressure > seed vapor pressure → SMC increases
- Seed vapor pressure > atmosphere vapor pressure → SMC decreases

Species	Temper. (°C)	Relative Humidity(%)					
		30	40	50	60	70	80
Field Bean	20	8.5	9.9	11.3	12.8	14.5	16.6
	28	8.3	9.7	11.1	12.6	14.3	16.4
	36	8.2	9.6	11.0	11.5	14.2	16.3
Soybean	20	7.2	8.0	9.1	10.7	13.1	15.4
	28	5.7	6.5	7.6	9.2	11.6	13.9
	36	4.2	5.0	6.1	7.7	10.1	12.4
Sorghum	20	9.6	10.8	12.0	13.0	15.1	17.4
	28	9.1	9.3	10.5	11.5	13.6	15.9
	36	6.6	7.8	9.0	10.0	12.1	14.4

ASAE (1980)



SEED WATER POTENTIAL

SEED WATER: characterized by an energy status and determined through a potential energy

Verifies whether a system is or is not water-balanced

$$\Psi_w = \Psi_m + \Psi_s + \Psi_p$$

Ψ_w = total water potential; Ψ_m = **matric potential**
 Ψ_s = **osmotic potential**; Ψ_p = **turgor potential**

Matric Potential and Osmotic Potential → **negative**
 Turgor Potential → **positive**

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SEED WATER POTENTIAL

Hydration process and hygroscopic equilibrium

Determination of seed water potential

Seed water content: water quantity in the sample

Water potential: water status and availability

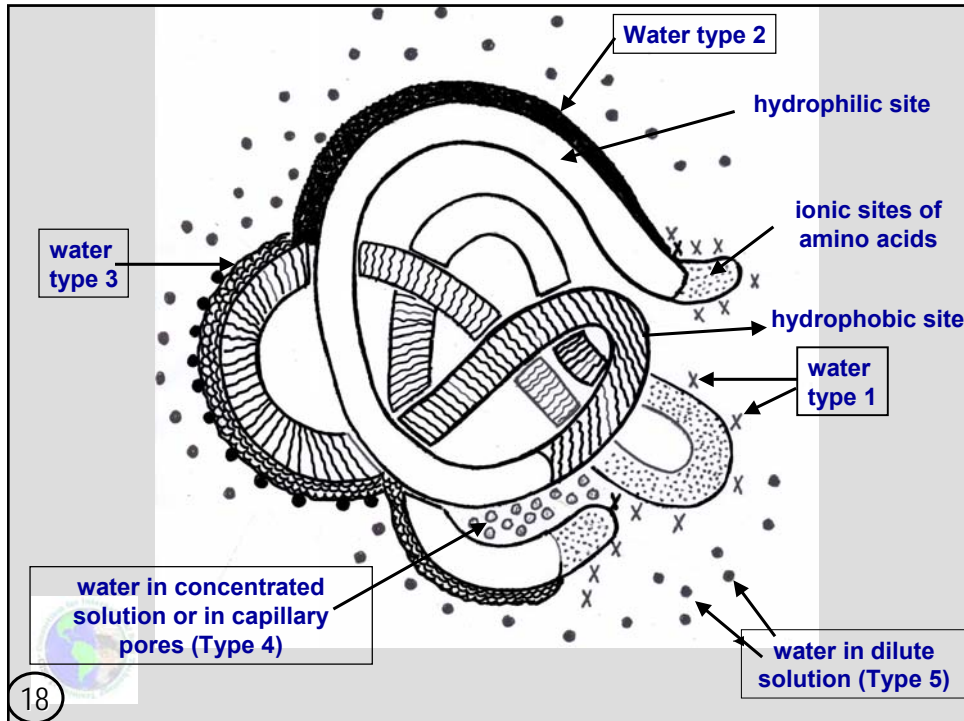


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WATER STATUS IN SEEDS



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WATER STATUS IN SEEDS

Water Type 5:

Seed tissues with > 41% water content

Characteristics of dilute solution

Water potential < -1.5 MPa

Free water

Water Type 4:

Seed tissues with 33% to 41% water content

Characteristics of a concentrated solution

Water potential -1.5 to -4 MPa

Remains in pores or capillaries, does not interact with the protein surface

WATER STATUS IN SEEDS

Water Type 3:

Seed tissues with 20% to 33% water content

Indication of freezable water

Water potential -4 to -11 MPa

Moistening of protein surface

Interacts with hydrophobic sites of macromolecules

Some glassy characteristics

Water Type 2:

Seed tissues with 7.5% to 20% water content

Forms a thin coat in the matrix surface

Water potential -11 to -150 MPa

Solvent role

Enzymatic, oxydative, catabolic reactions

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WATER STATUS IN SEEDS

Water Type1:

Very dry seeds : < 7.5% water content

Structural water

Removal: oxidative reactions (low protection)

Relative Humidities (independent of species and seed tissues):

Water Type 1: equilibrium with < 30% R.H.

Water Type 2: equilibrium with 30 - 85% R.H.

Water Type 3: equilibrium with 85 - 92% R.H.

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WATER STATUS IN SEEDS

TYPES	Water Potential (MPa)	Water Content (%)	
		Dw(‡)	Fw
1	< -150	< 8.0	< 7.5
2	-150 to -11	8 to 25	7.5 to 20
3	-11 to -4	25 to 45	20 to 33
4	-4 to -1.5	45 to 70	33 to 41
5	> -1.5	> 70	> 41

(‡) Dw = water content , dry weight basis


Fw = water content , fresh weight basis



IMPORTANT SEED PHYSIOLOGICAL AND TECHNOLOGICAL EVENTS ASSOCIATED WITH SEED WATER CONTENT AND WATER STATUS




Water Content (%)	Type of Water	Events
> 41	5	Physiological maturity in dicots Start of metabolism for dicot seed germination Germination completed
30 – 40	4	Protein and nucleic acids synthesis during seed maturation and germination Activity of membrane and DNA repair mechanisms Recalcitrant seed storage High sensitivity to freeze injury
18/20 - 30	3	Intense seed respiration and heating of seed mass during storage Deterioration is accelerated Intense microorganism activity Minimum levels of enzymic activity in anabolic processes Membrane organization ATP synthesis Recalcitrant seed storage Removal is usually lethal to recalcitrant seeds



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Water Content (%)	Type of Water	Events
12/14 to 18/20	2	Respiration is reduced, but some risk of heating persists Minimum level for synthesis reactions catalyzed by enzymes Seed deterioration during storage Significant activity of fungi and insects during storage Adequate for mechanical harvest Lower sensitivity to mechanical injuries (moisture content 13% - 16%)
10 to 13	2	No synthesis reactions Rate of deterioration is reduced Acceptable for storage in porous or resistant packing to water vapor exchange Insect occurrence
< 10	2	Drastic reduction of insect activity Favorable to seed storage in hermetical packets
4 to 8	1	Possibility of seed dormancy or lipid autooxidation Water removal may increase seed deterioration Protection against free radical effects



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