Irrigation

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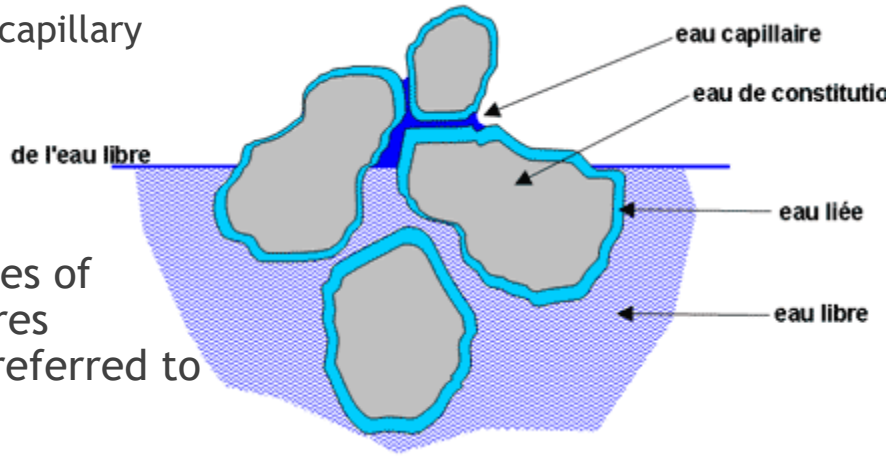
CLIMAX CONSEILS

1- Understanding the availability of water for crops

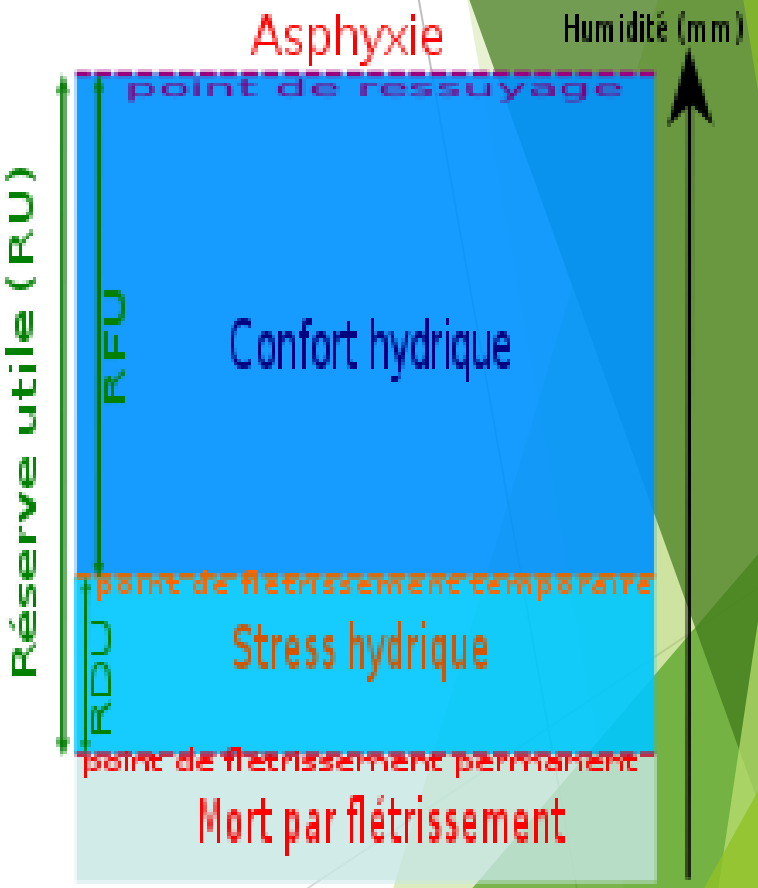
- The different kinds of water in the soil
  - Free water (gravitational): Water that flows by gravity following a heavy rain
    - Located in areas where the pores are too large (macroporosity) to create a capillary action effect
    - The water will give way to air by draining.
    - After drainage, field saturation is reached.
  - Capillary water (matric force): Water that is primarily held by the forces of cohesion between water molecules. This takes place in the smaller pores (microporosity) and constitutes the water available for plants. This is referred to as available water capacity (AWC).
  - Bound water: Water held firmly by soil particles (hygroscopic). This water is too strongly held to be accessible to plants. It is bound water.
  - Water of constitution: Water retained by solid chemical bonds (e.g., Epsom salts)



https://dorossinet.blogspot.com/2016/11/cours-svt-tronc-commun-bac_21.html

1- Understanding the availability of water for crops

- Available water capacity (AWC)
  - Available water: Hydric comfort zone
  - Slightly available water: Temporary wilting zone



https://fr.wikipedia.org/wiki/R%C3%A9serve_utile_en_eau_d%27un_sol

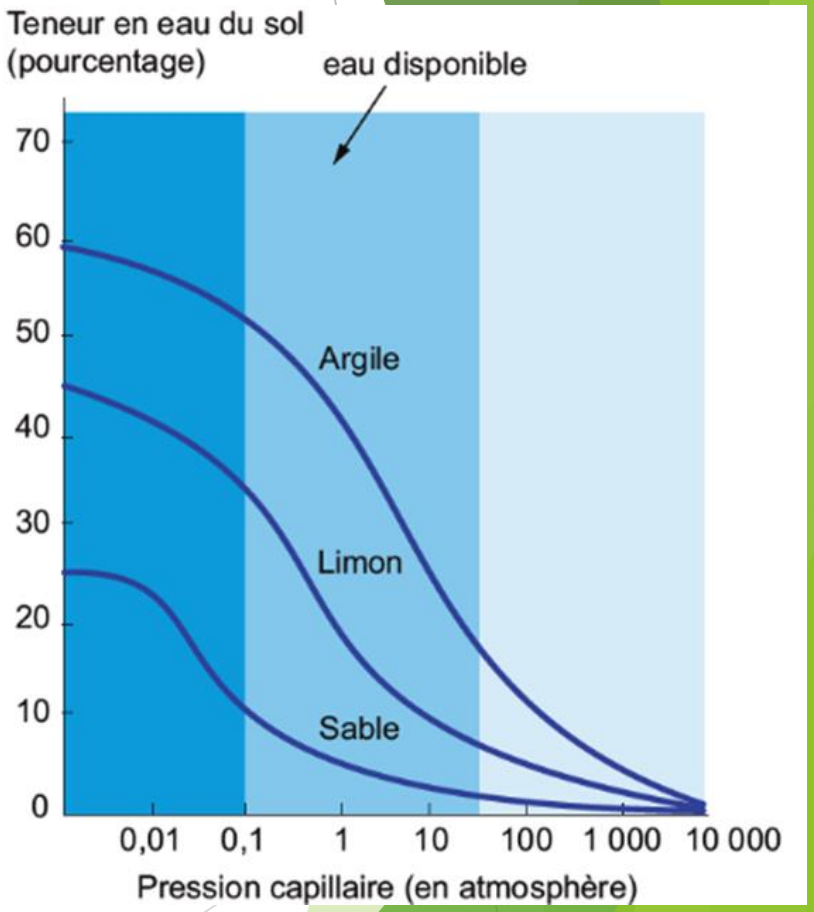
1- Understanding the availability of water for crops

- Available water capacity (AWC)
  - Available water: Hydric comfort zone = available water
  - Slightly available water: Temporary wilting zone (before the point of permanent wilting)

capacité de rétention d'eau d'un sol (mm/cm)

Texture	Capacité de terrain	Point de flétrissement	Eau disponible
Sable grossier	0,6	0,2	0,4
Sable fin	1,0	0,4	0,6
Sable limoneux	1.4	0,6	0,8
loam sableux	2.0	0,8	1.2
Loam sablo-argileux léger	2.3	1,0	1.3
Terreau	2.7	1.2	1.5
Limon argilo-sableux	2.8	1.3	1.5
Terreau d'argile	3.2	1.4	1,8
Argile	4.0	2.5	1.5
Argile auto-mulching	4.5	2.5	2.0

www.aquaportail.com



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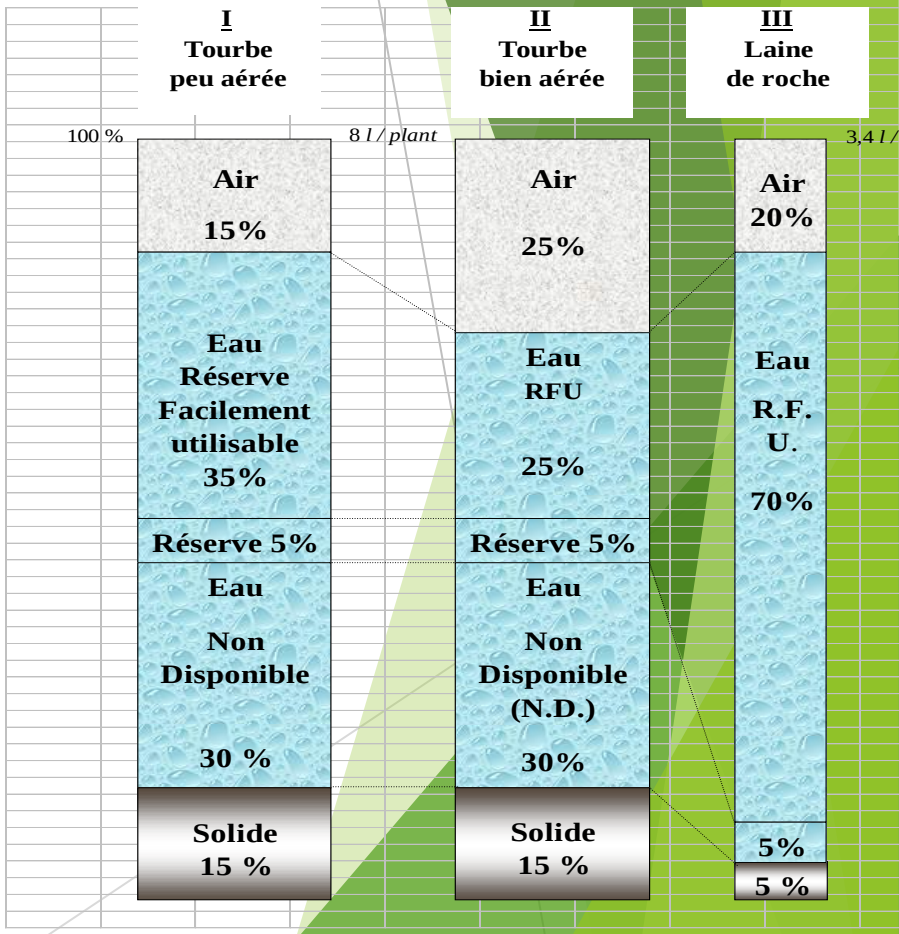
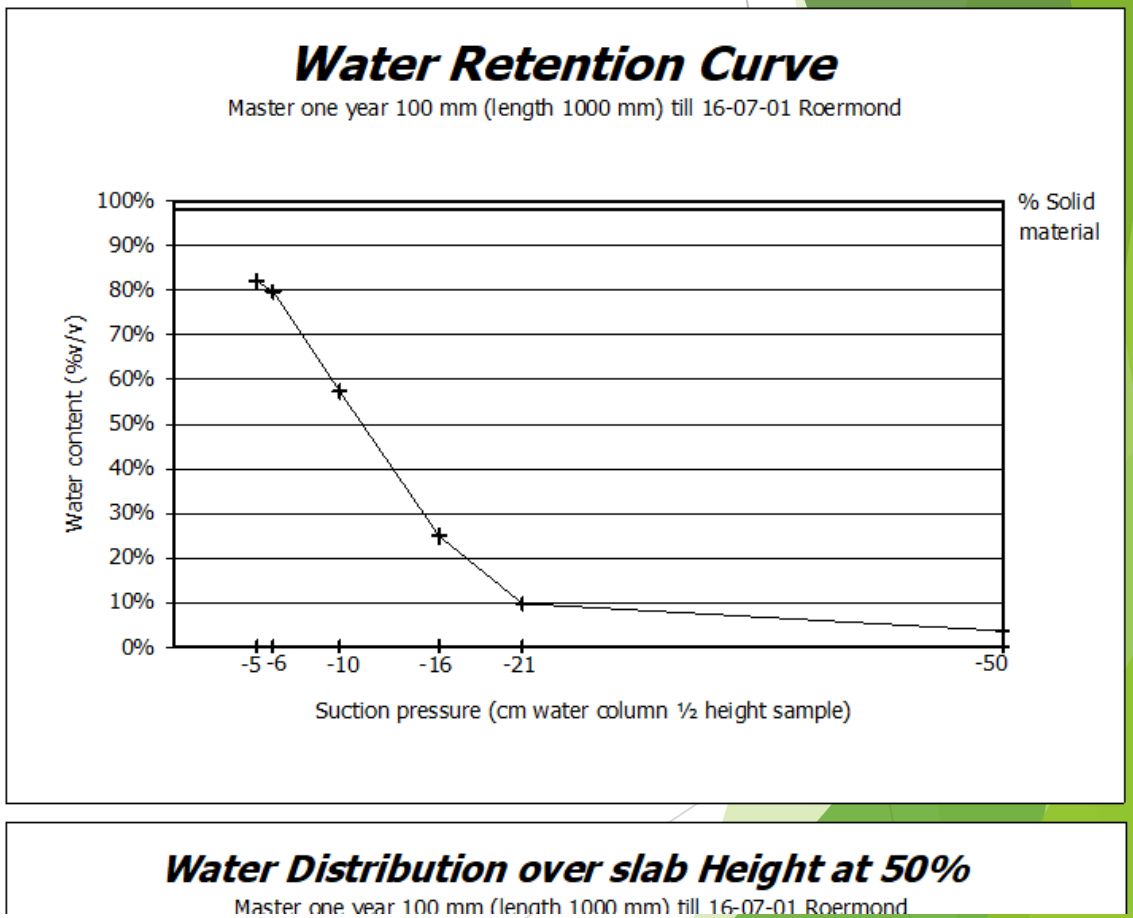


Source: Climax Conseils

1- Understanding the availability of water for crops

- Rock wool
  - Almost nil matric force
    - Required perfect levelling
    - High available water (70%)
  - Good macroporosity (20%)
  - Very precise microporosity (large diameter)

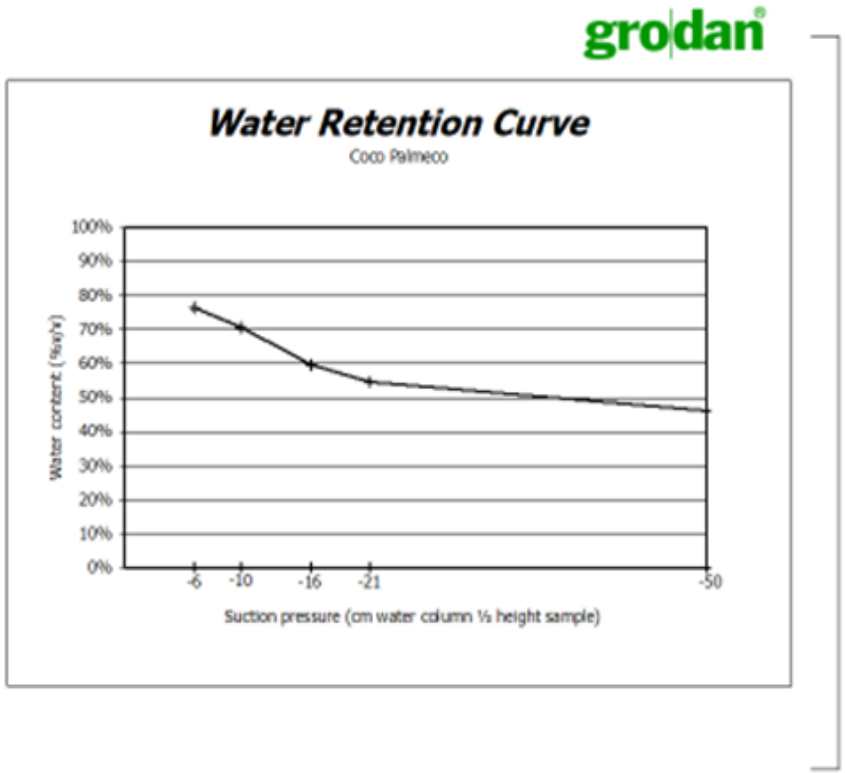
Master grodan®



1- Understanding the availability of water for crops

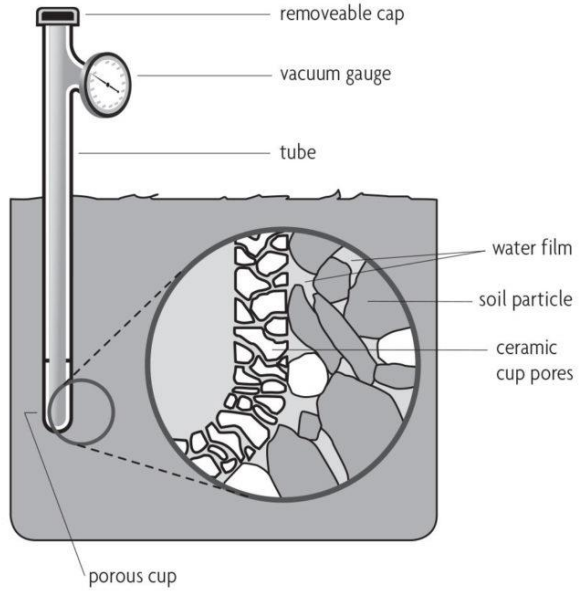
- Coconut fibre
  - Strong matric force
    - Required moderate levelling
    - Low available water (30%)
- Good macroporosity (25%)
- Good microporosity but variable diameter

Courbe de tension Coco



1- Understanding the availability of water for crops

- Measurement by tensiometer
  - Measurement of tension by capillary force of porous ceramic
    - The force (tension) measured is what is balanced between the capillary force of the soil and that of the ceramic
    - It is measured in kPa (kilopascal)
    - 1 kPa = 10 cm What does that mean?
  - Typically desired maximum tension
    - Field soil: 10 kPa
    - Greenhouse soil: 6.5 kPa
    - Hydroponic substrate: 4.5 kPa



https://www.sare.org/publications/conservation-tillage-systems-in-the-southeast/chapter-14-water-management/monitoring-soil-water/

1- Understanding the availability of water for crops: practical case

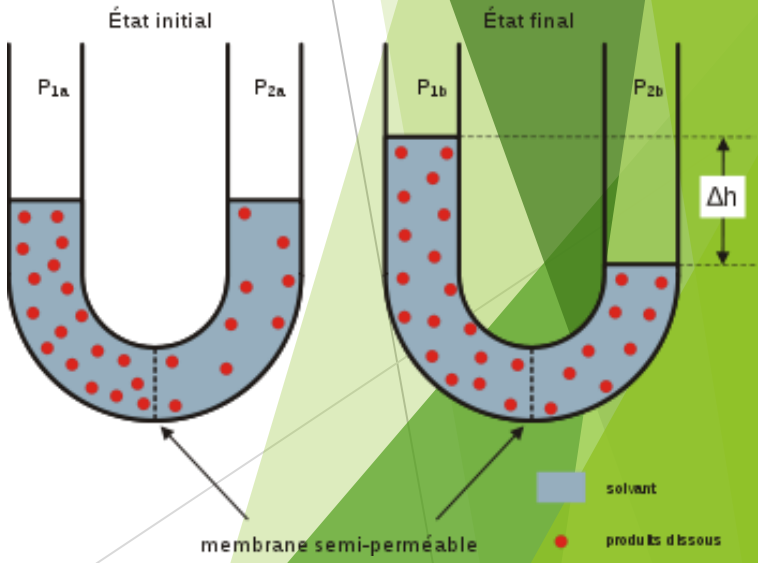
Sequence of substrates: Observing capillary action

Table 1: From wettest to driest

	Stage			
	Planting	Subculture	Seedling	Siphon
Substrate	Rock wool	Rock wool	Rock wool	No
	Sawdust	Rock wool	Rock wool	No
	Peaty mix	Peaty mix	Peaty mix	No
		Rock wool	Rock wool	Yes
	Coconut fibre	Rock wool	Rock wool	Yes
	Soil	?	?	Yes/No

1- Understanding the availability of water for crops

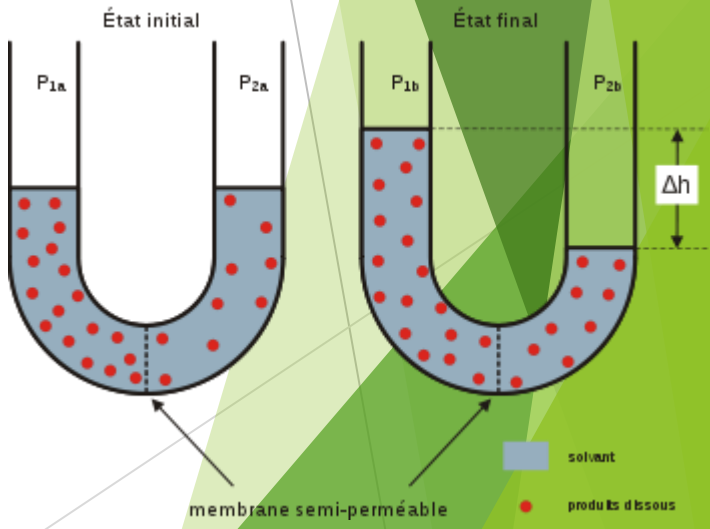
- Salinity: Osmotic effect
  - The root is a semi-permeable membrane
    - Lets the water through but not the minerals
    - The water will seek to balance the concentration of the two sides of the membrane
    - The water will stop when the water buoyancy (cm of water column) is equal to the osmotic force Δh = the water column pressure
  - The salts in the root therefore compete with the salts in the root environment to attract water.



https://fr.wikipedia.org/wiki/Osmose

1- Understanding the availability of water for crops

- Salinity: Osmotic effect
  - How is it measured?
    - It is hard to measure this pressure in production conditions
    - Indirect measurement using the conductive properties of the salts = Electrical conductivity
      - Caution, only measures what has positive and negative loads (salts)
        - Urea is a neutral element; it is not measured but has osmotic effect
      - A measured value is only valid when the mineral content is fairly well known.
        - Osmosis is created by the number of atoms and molecules, not electric loads.



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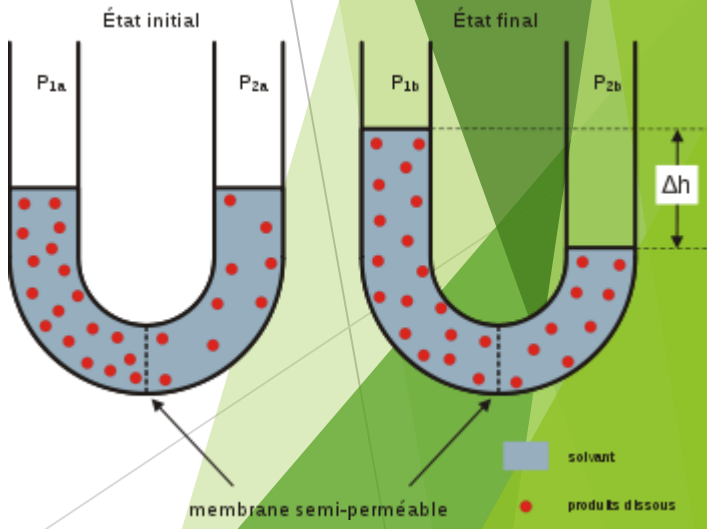
1- Understanding the availability of water for crops

- Salinity: Osmotic effect
  - How is it interpreted?
    - 1 mS/cm = 33.3 kPa = 333 cm of water column = 4.78 psi; it is high!!!
      - 6 mS/cm = 200 kPa = 2,000 cm of water column = 28.68 psi; it is heavy
        - Your plant has to fight against it for water uptake



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1- Understanding the availability of water for crops

- Hydroponic
  - Matric tension
    - Day: -1 kPa
    - Night: -4.5 kPa
  - Osmotic tension
    - Electrical conductivity (EC)
      - Tomato in the summer =
        - Night: 4.5 mS/cm = -150 kPa
        - Day: 2.5 mS/cm = -83 kPa
          - Increases quickly
          - Plant adaptation

The osmotic effect dominates

- Soil
  - Field crops: Matric tension
    - -10 kPa
    - Low EC

    The tension dominates
  - Greenhouse
    - Matric tension
      - Day: -1.5 to -6 kPa (field capacity)
      - Night: -3.5 to -6.5 kPa
    - Osmotic tension
      - EC (SSE)
        - Tomato: 2.5 mS/cm = -83 kPa
          - Plant adaptation
          - Fertility to be maintained
    - The osmotic effect dominates

1- Understanding the availability of water for crops

When osmotic potential is your only tool!!!

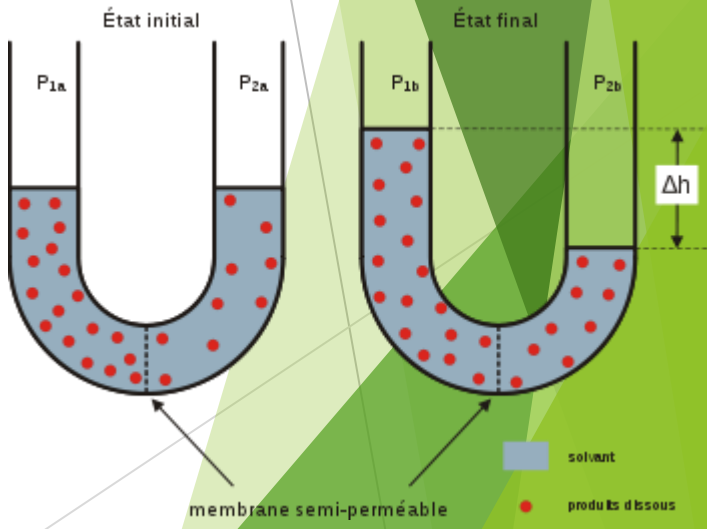
Nutrient film technique (NFT)

Aeroponics

Growing produce on mobile floats

1- Understanding the availability of water for crops

- If salinity is so important, why measure tension in a greenhouse?
  - To monitor water content
    - Drier = equals more saline (salt concentration effect)
    - Aeration
  - A good greenhouse soil is well aerated at saturation
    - Ideally loam and coarser



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1- Understanding the availability of water for crops

- **Measuring osmotic effect = Electrical conductivity meter**

2- Understanding the water needs of crops

Irrigation in field soil: Camel type – approximately 1 X every 6 days

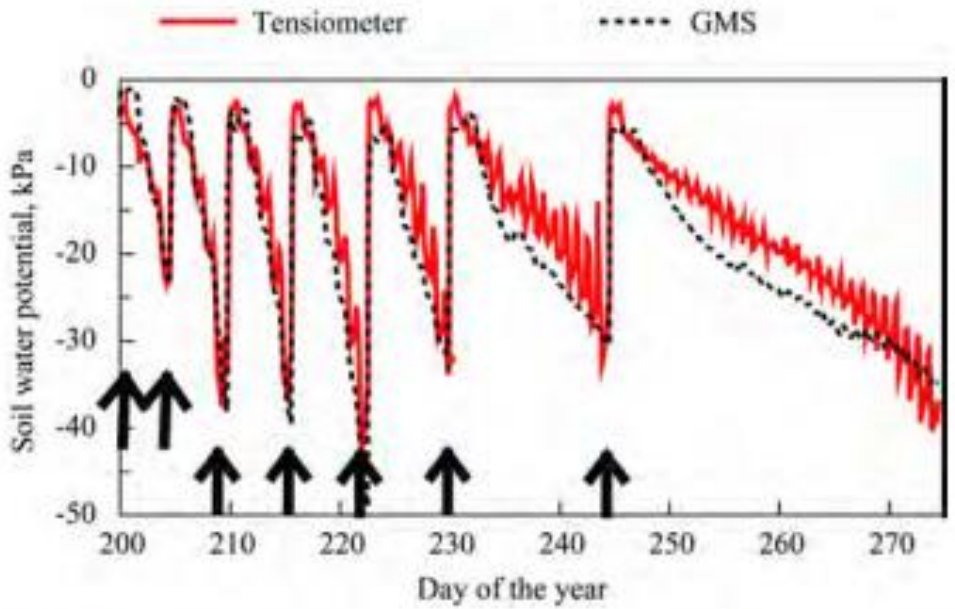
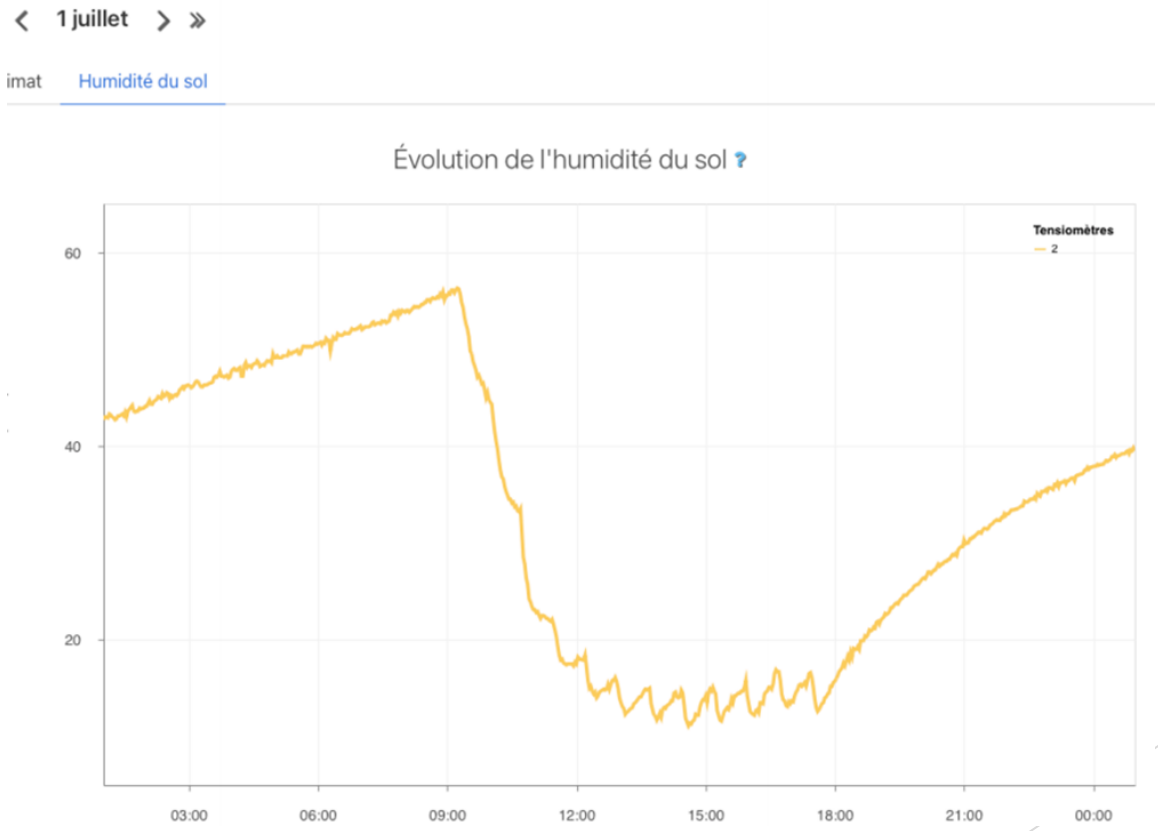


Figure 7. Soil water potential over time for tensiometers with transducers and granular matrix sensors in Experiment 3. Arrows denote furrow irrigations with 75 mm of water applied. Malheur Experiment Station, Oregon State University, Ontario, OR, 2004.

Shock et al. 2016
Journal of Water Resource and Protection, 2016, 8, 154-167

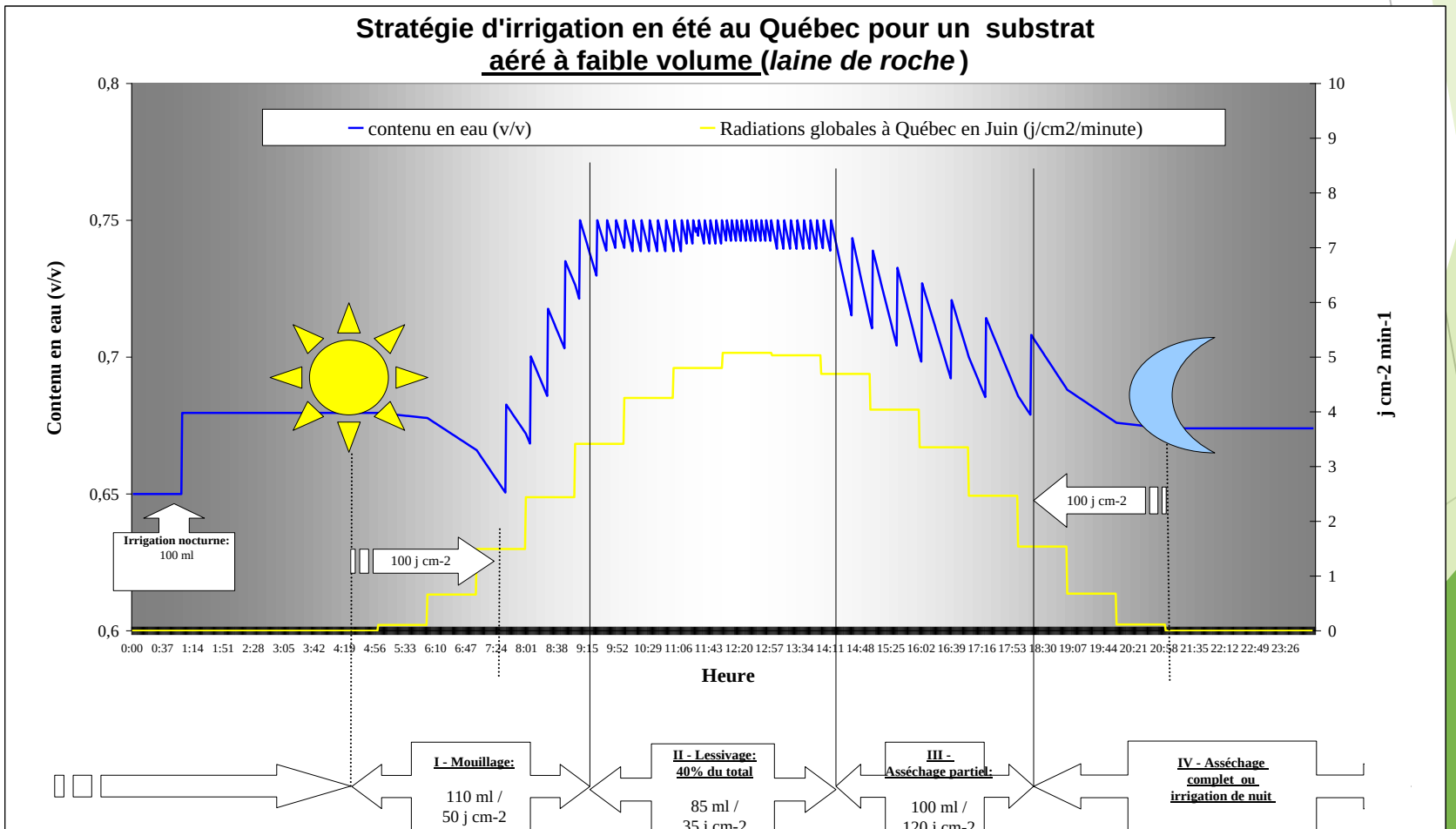
2- Understanding the water needs of crops

Irrigation in greenhouse soil: Tension curve – Sandy soil (mb=0.1 kPa)
11 waterings



2- Understanding the water needs of crops

Irrigation in hydroponics for greenhouse vegetables: Marathon-style – up to 25-30 waterings/day



Source : Climax Conseils

2- Understanding the water needs of crops

A plant is also a living thing that must face several factors:

- Thin leaves: dry very fast
- Sun of up to nearly 1,000 W/m^2 in the summer = 1 hair dryer / m^2
- If it cannot cool quickly, it will burn

The primary reason for watering in the summer is to allow the plant to

COOL DOWN

(TOUCH THE FOLIAGE IN THE SUMMER)

2- Understanding the water needs of crops

A plant is also a living thing that must face several factors:

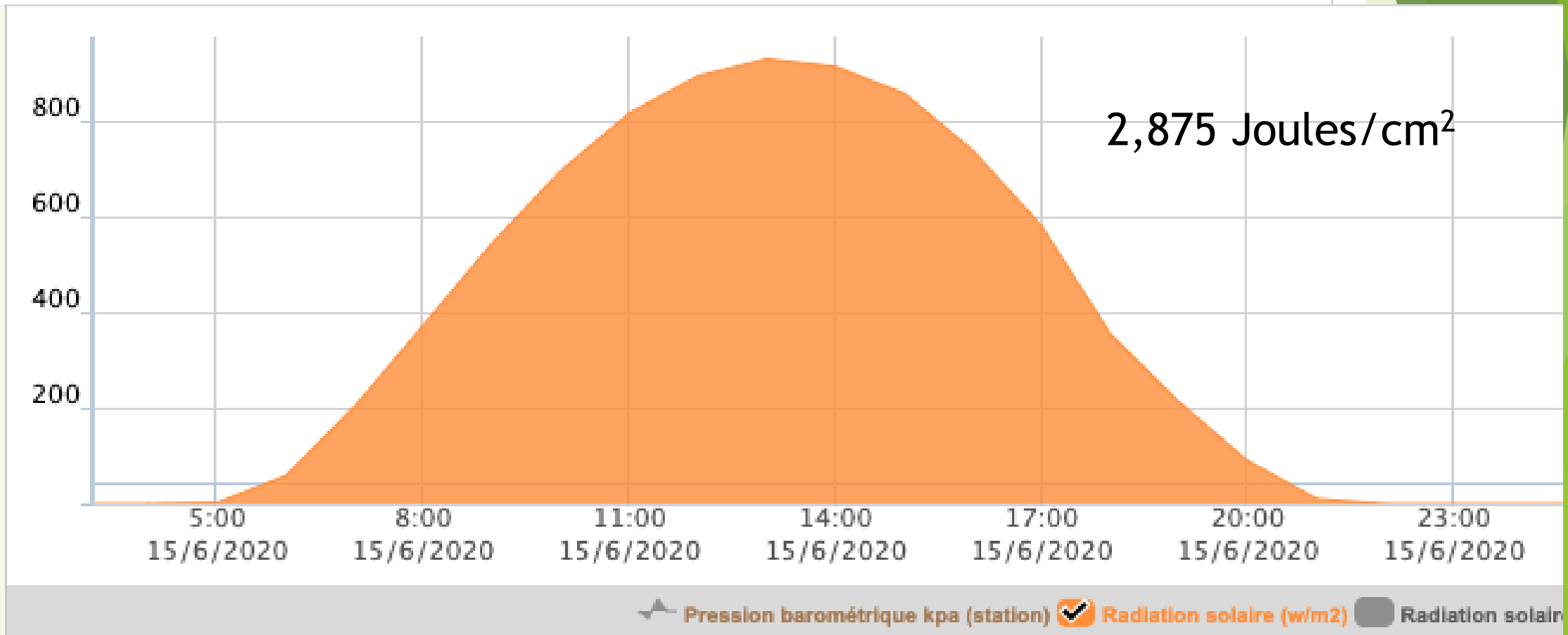
- In summer: 16 hours of endurance = Marathon = staying on the hydration line:
  - Hydroponic: Marathon waterings
  - Soil: Marathon – not watering for the soil, but for the plant
    - But there are structural constraints:
      - Soil water retention X large volume: Hard to dry (aerate) quickly
      - Irrigation system: drip tape vs. uniformity = requires long irrigations
    - Buffer effect: Provides benefits in the event of equipment failure or technological limitations (it is almost possible start watering manually)

2- Understanding the water needs of crops

Major factors in water consumption: The sun varies over time

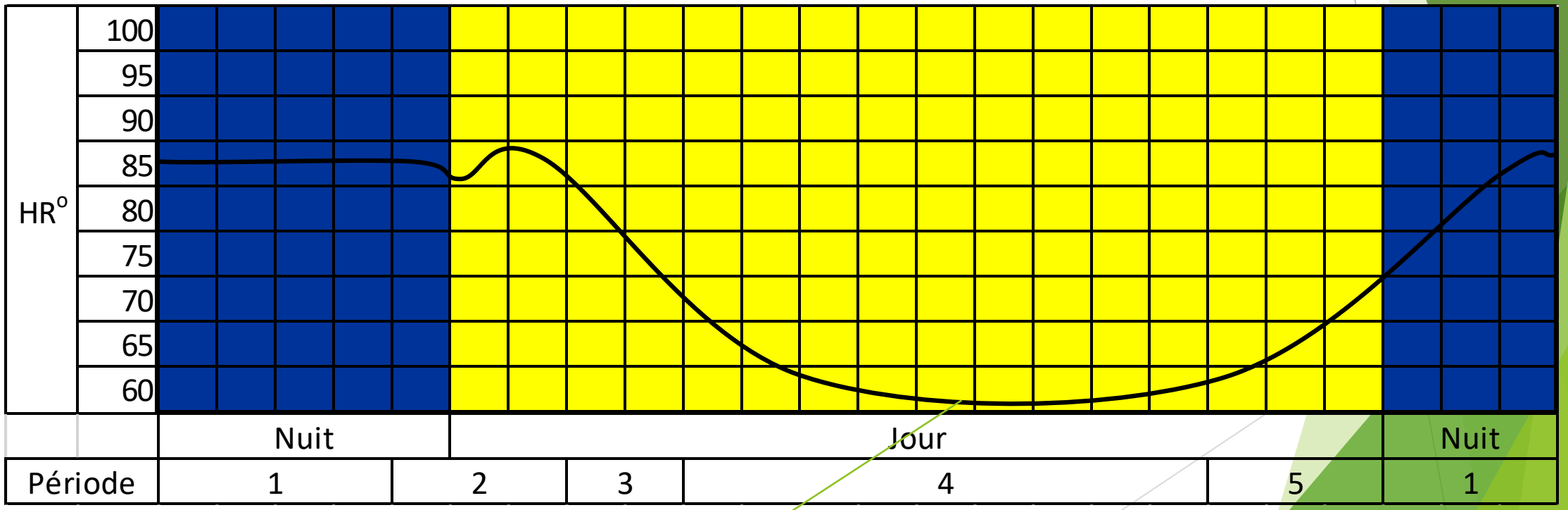
Light curve, June 15, 2020
Quebec City Airport

AgWeather Meteogram



2- Understanding the water needs of crops

Major factors in water consumption: Daily summer relative humidity (humidity deficit increased from 3 to 15 g/m^3)



1000 W/m^2 . 28°C, DH = between 13 and 15 g/m^3

Source : Climax Conseils

2- Understanding the water needs of crops

Purpose of irrigation management

- Maintain a balanced tension (marathon = just in time) between the plant and its environment:
  - Meet the cooling needs of foliage
  - Turgidity for cell growth
  - Mineral input
  - Maintain vegetative/reproductive balance, fruit quality and root aeration

2- Understanding the water needs of crops

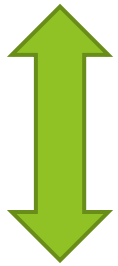
This balance is known as water balance: Soil-plant-environment continuum

- Availability of water
  - Soil tension
  - EC (electrical conductivity) = saline effect
- Evapotranspiration
  - Sunshine (variable from 0 to 1000 W/m^2)
  - VPD, HD, RH^o X T^o = Drying effect
  - Boundary layer (air movement)

3- Understanding the air needs of crops

Irrigation issues:

Aeration



Availability of water: Tension, salinity, capillary movements

3- Understanding the air needs of crops

Aeration

- % of air at saturation:
  - Technical substrate: 25% of air on the entire substrate
    - 20% in rock wool is good (very good gas diffusion and piston effect of irrigations)
  - Soil:
    - Minor issue in fields
    - Significant issue in greenhouses in heavy soil, clayish and finer loams rejected
- % air in soil drainage (ensure aeration of deep roots at night)
  - Technical substrate: Bottom of bag effect (25% of air in the bottom of the bag in the morning)
  - Difficult to create a difference in soil aeration (too high volume); aeration must be structural

The purpose of irrigation management is therefore to:

1- Ensure water availability

2- Ensure good root aeration

We must therefore learn to:

1- Water

2 - Let dry (restore aeration)

I water, I dry, I water, I dry, I water, I dry, I water, I dry, I water, I dry

4- How much time is needed to dry the root environment?

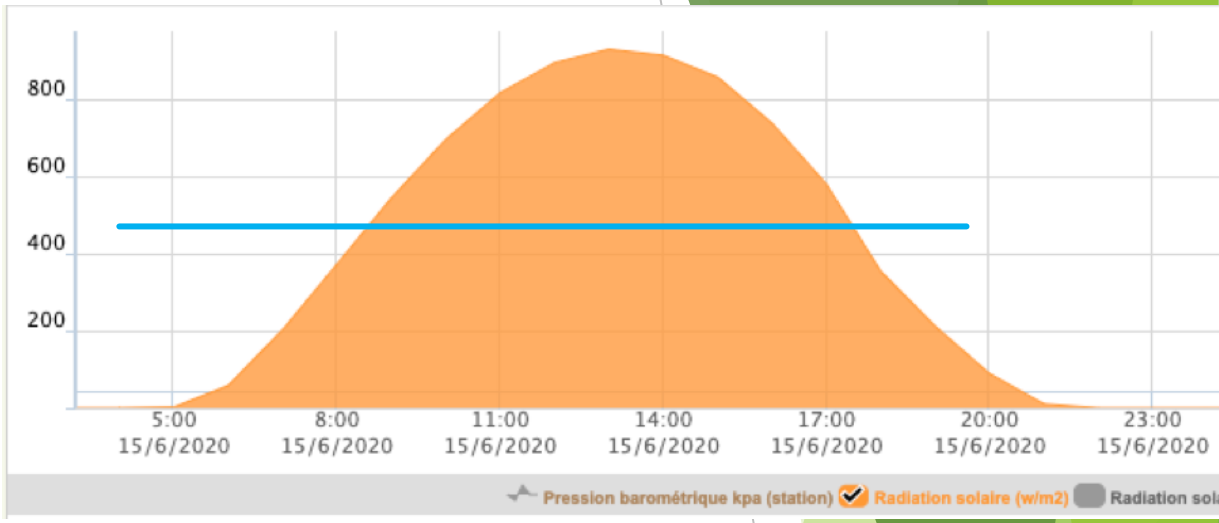
Speed of water uptake
vs.
Substrate characteristics

4- How long does it take to dry?

- Speed of water uptake:
  - Intensity of the sun (W/m^2)
  - Stage of the crop (m^2 leaves / m^2 soil)
- Speed of drying (aeration)
  - Determines the watering intervals
    - Speed of consumption
    - Substrate volume (soil) ($Litres/m^2$)
    - Available water

Speed of water uptake

How is light measured?



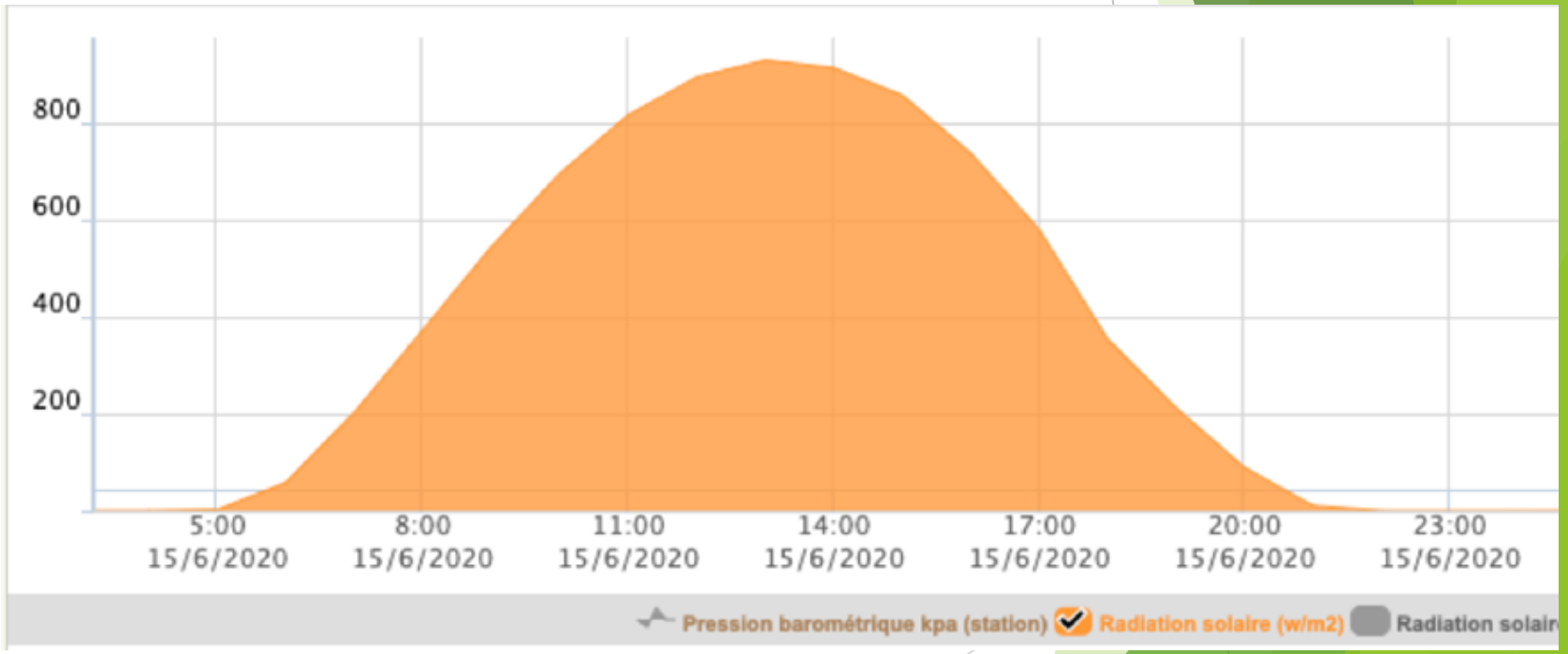
- **Formula: Joules/cm^2 or J/cm^2**
  - Intensity = Watt/m^2
  - Watt = Joule/second
  - Intensity on June 21 at noon: 1,000 W/m^2
  - Cumulative:
    - 1,000 W/m^2 X 60 minutes/hr X 60 seconds/min = 10,000 cm^2/m^2
    - 360 J/cm^2
    - 490 W/m^2 X 60 min/hr X 60 sec/min X 16 hours/10,000 cm^2/m^2 =
    - 2,822 J/cm^2

Speed water uptake

- Total daily consumption
  - Type of greenhouse:
    - 1-2: 1.8 mL/joule X 2,822 j/cm^2 = 5,080 mL/m^2
    - 3: 1.4 mL/joule X 2,822 j/cm^2 = 3,951 mL/m^2
    - 4: 1.25 mL/joule X 2,822 j/cm^2 = 3,527 mL/m^2
  - If you have 1,000 W/m^2 in a type 2 greenhouse, how many mL/m^2 are consumed in one hour?
  - Do the calculation for 100 to 1,000 W/m^2 in increments of 100 W.

360 joules X 1.8 mL/joule = 648 mL

- 100 W = 64.8 …..
- Each hour could be calculated but!!!



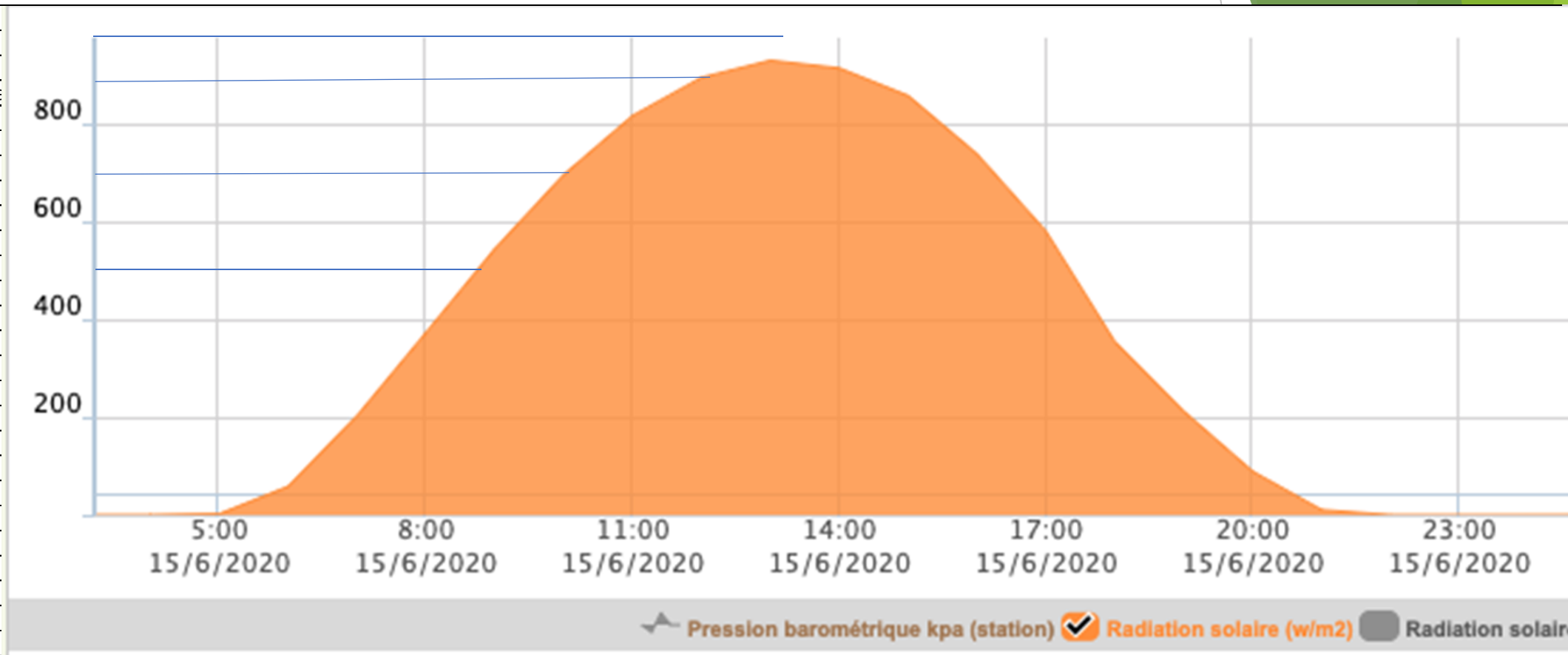
Speed of water uptake

Consumption type 2 greenhouse: 1.8 mL/joule					
Month	**Brightness (j/cm2/day)**			**Consumption (mL/m2/day)**	
	Nice day	**Average[1]**	**Cloudy[2]**	**Average[1]**	**Cloudy[2]**
January	500-800	400	200	720	360
February	1,200 – 1,500	650	325	1,170	585
March	1,800	1,000	500	1,800	900
April	2,500 – 2,800	1,450	725	2,610	1,305
May	2,500 – 2,900	1,700	850	3,060	1,530
June	2,500 – 2,900	1,850	925	3,330	1,665
July	2,800 – 2,500	1,920	960	3,456	1,728
August	2,400 – 2,000	1,750	875	3,150	1,575
September	1,700 – 1,200	1,196	598	2,152.8	1,076.4
October	1,200 – 1,100	806	403	1,450.8	725.4
November	800 – 700	453	226.5	815.4	407.7
December	600 – 500	419	209.5	754.2	377.1

1- Can vary considerably by region
2- Estimated at 50% of average

Sample calculation (for patient people)

Joules tot	2875	
mL/m2/jour	5175	
Culture	Concombre	
Substrat	Sable	
Type de serre	2	



		Corr			30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	Tot		
Watt/m2 (100%		0	0	0	12	50	162	375	530	700	860	930	980	930	860	700	530	375	162	50	12			
J/cm2/hr (100%)			0	0	4,32	18	58,32	135	190,8	252	309,6	334,8	352,8	334,8	309,6	252	190,8	135	58,32	18	4,32	2958,5	2875	
ml/m2/hr (100%)		0	0	0	7,776	32,4	104,98	243	343,44	453,6	557,28	602,64	635,04	602,64	557,28	453,6	343,44	243	104,98	32,4	7,776	5325,3		
ml/m2/hr (80%)		0	0	0	6,2208	25,92	83,981	194,4	274,75	362,88	445,82	482,11	508,03	482,11	445,82	362,88	274,75	194,4	83,981	25,92	6,2208	4260,2		
ml/m2/hr (60%)		0	0	0	4,6656	19,44	62,986	145,8	206,06	272,16	334,37	361,58	381,02	361,58	334,37	272,16	206,06	145,8	62,986	19,44	4,6656	3195,2		
ml/m2/hr (35%)		0	0	0	2,7216	11,34	36,742	85,05	120,2	158,76	195,05	210,92	222,26	210,92	195,05	158,76	120,2	85,05	36,742	11,34	2,7216	1863,8		

5- The basics of irrigation:

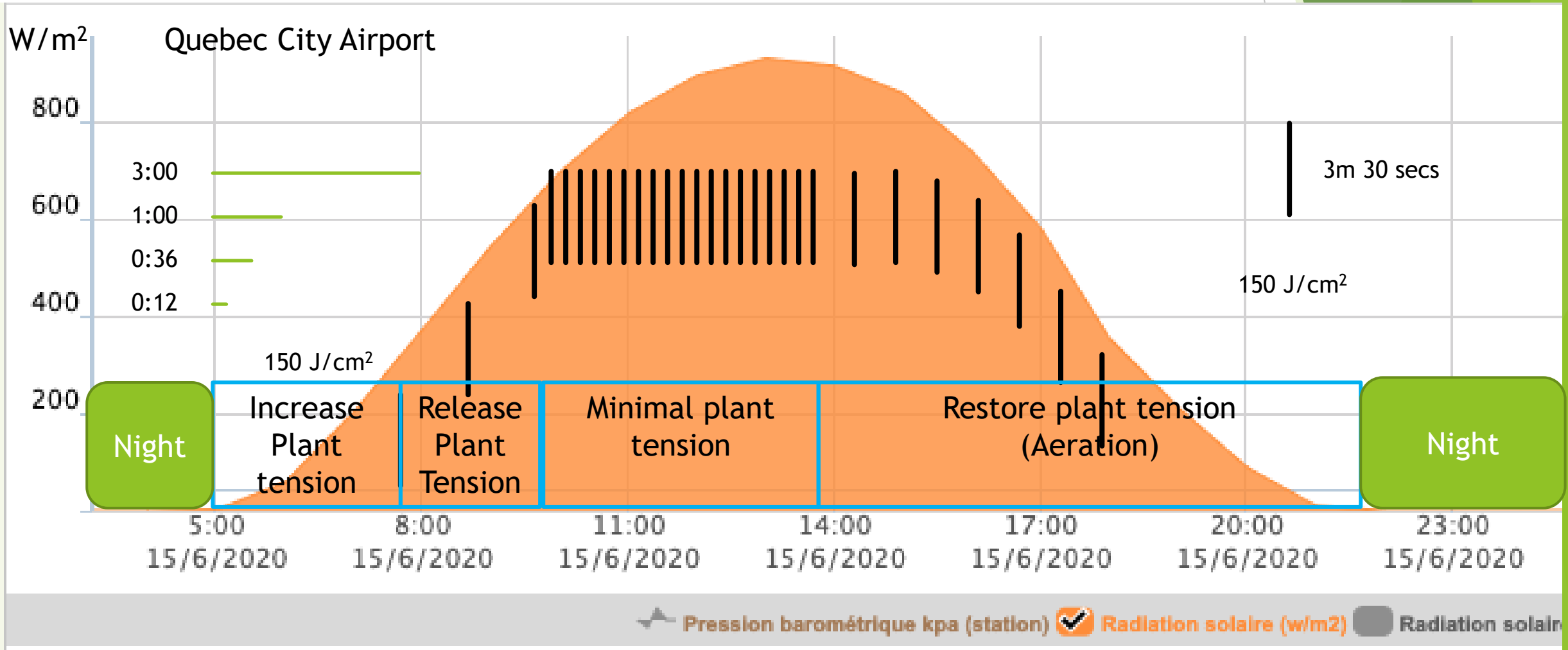
a- Ensure water availability

b- Ensure good root aeration

How to do it?

5- The basics of irrigation: The 5 stages

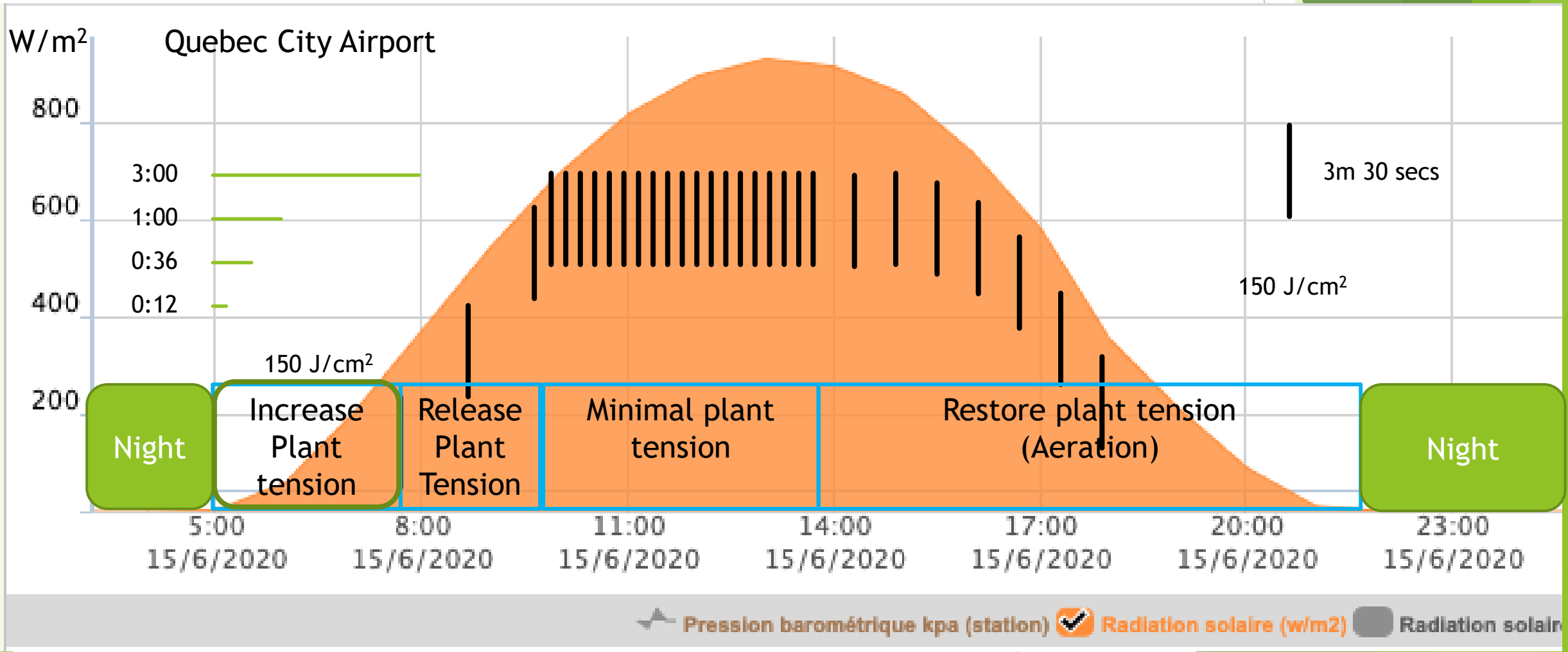
Light curve, June 15, 2020 (week 25)



AgWeather Meteogram

5- The basics of irrigation: Stage 1

Light curve, June 15, 2020 (week 25)



AgWeather Meteogram

5- The basics of irrigation: Stage 1

- Stage 1: Increase plant tension = no watering
  - Let the plant be thirsty
    - Water buffer effect of the plant, greenhouse 1-2 (Build the continuum air-plant-substrate)
      - Beef tomato loaded: 2.5 hours in summer
      - Cucumber and cherry tomato: 1.5 hours in summer
      - Pepper: 1 hour in summer
    - Time to build tension in the substrate = activation of roots
      - 0.5 hour

5- The basics of irrigation: Stage 1

Time: start watering based on joules = End of increase plant tension stage

Effect of type of greenhouse on irrigation

Tomato **Week: 25**

Type	1 or 2 100%	3 78,6%	4 68,8%
Actions			
Start of watering	150 J/cm²	191 J/cm²	218 J/cm²
No. hours AS	3:00	3:15	3:22
Actual time	7:50 a.m.	8:05 a.m.	8:12 a.m.

Effect of type of greenhouse on irrigation

Cucumber **Week: 25**

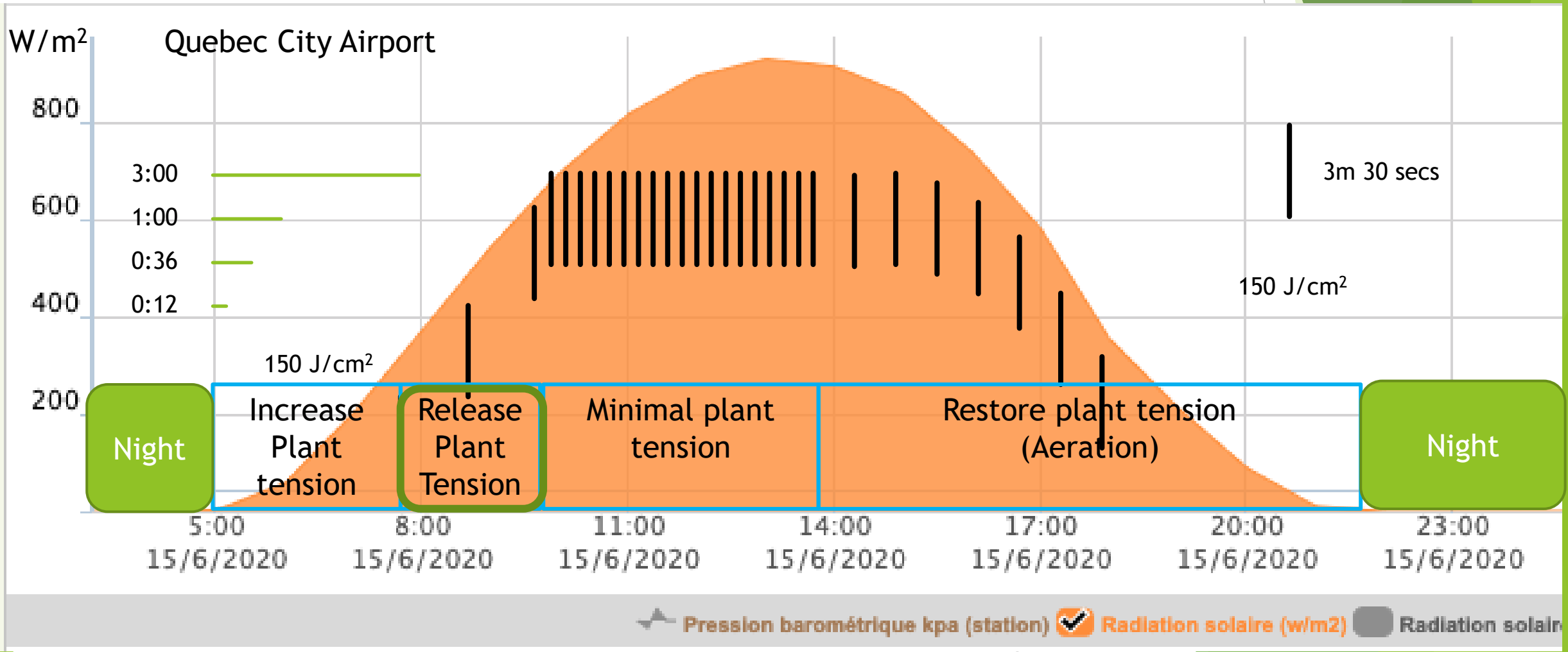
Type	1 or 2 100%	3 78,6%	4 68,8%
Actions			
Start of watering	100 J/cm²	127 J/cm²	145 J/cm²
No. hours AS	2:00	2:20	2:30
Actual time	6:50 a.m.	7:10 a.m.	7:20 a.m.

Tension increasing period is independent of the substrate but dependent on the crop

Source : Climax Conseils

5- The basics of irrigation: Stage 2

Light curve, June 15, 2020 (week 25)



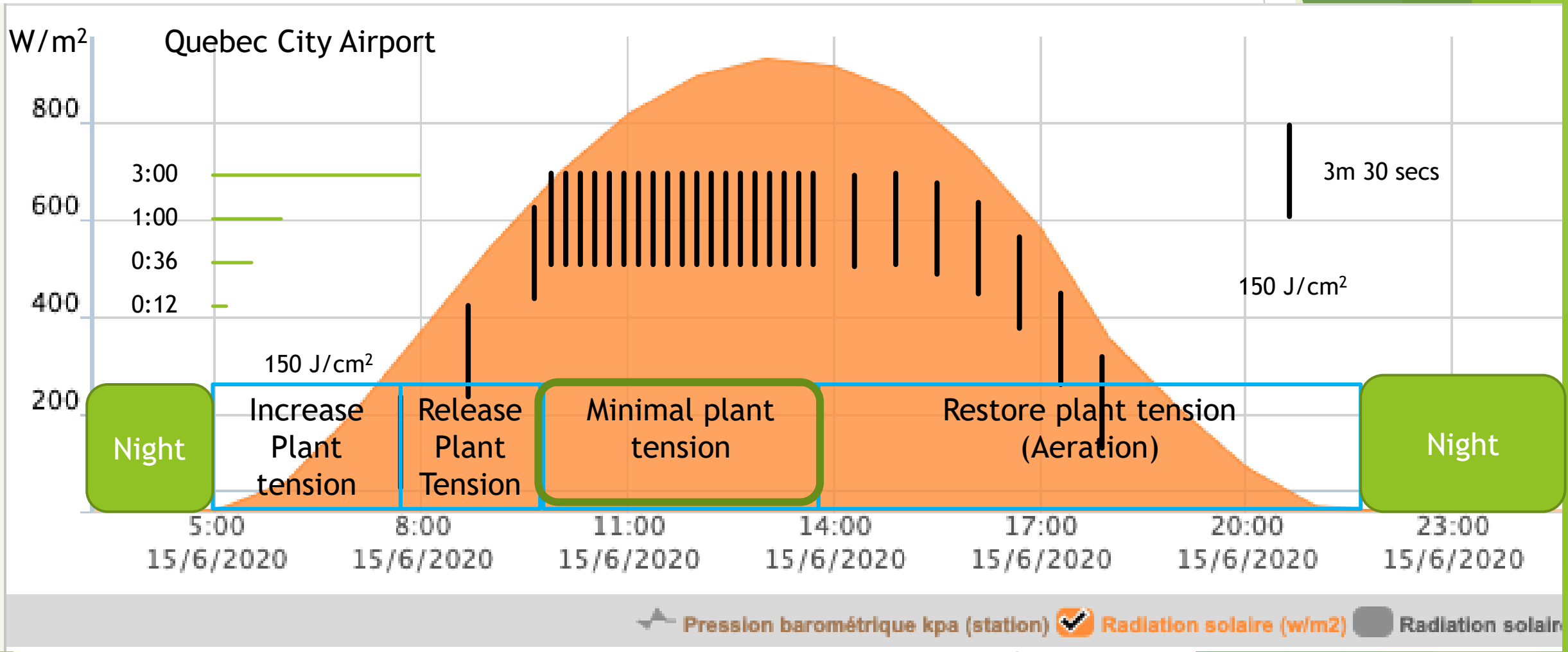
AgWeather Meteogram

5- The basics of irrigation: Stage 2

- Stage 2: Release plant tension = Moistening
  - Monitor the transpiration demand of the climate until minimum tension
  - Total volume = mL/joule X (joules at end of day + joules before minimum plant tension)
    - About 10% of the volume of the substrate in hydroponics
    - Transition from the granular stage to the saturated soil stage (when possible)
      - -4 kPa (Dorais, et al., 2009)
      - -6.3 kPa (Sonneveld and Voogt, 2009)

5- The basics of irrigation: Stage 3

Light curve, June 15, 2020 (week 25)



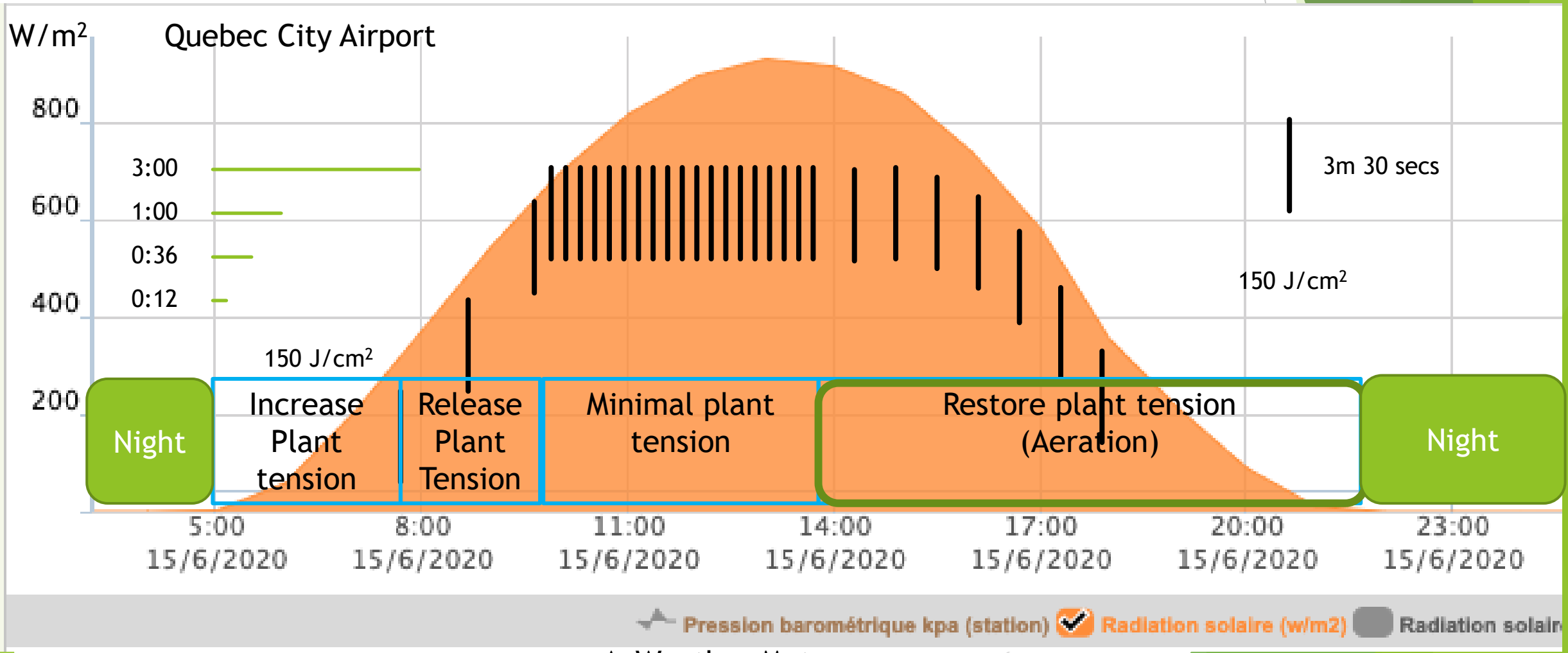
AgWeather Meteogram

5- The basics of irrigation: Stage 3

- Stage 3: Minimal plant tension = Peak cooling requirement period
  - Meet the maximum transpiration demand of the climate
    - Hydroponics: Leaching period
    - Soil: Maximum moistening; low tension is maintained

5- The basics of irrigation: Stage 4

Light curve, June 15, 2020 (week 25)



AgWeather Meteogram

5- The basics of irrigation: Stage 4

- Stage 4: Restore plant tension – Night drying
  - Restore tension for the night (the climate continues to be monitored); water if drying is too fast
  - Ensure aeration of roots at night
  - Slowing of consumption by joule received
    - Water buffer effect
      - Beef tomato: Water uptake slows quickly but continues for a long time (night irrigation in hydroponics)
      - Other: Water uptake slows one hour later but remains fairly close to climate demand from the sun

5- The basics of irrigation: Stage 4

- Stage 4: Tension restored = Night drying
  - Low volume substrate or sand
    - One hour after the zenith in the summer for beef tomatoes (2 hours in heat waves), one hour later for other crops
      - Summer: 2:00 p.m. beef tomatoes and 3:00 p.m. cucumbers in the summer
      - Heat wave: 3:00 p.m. tomatoes and 4:00 p.m. cucumbers in a heat wave
      - You give water only to slow down the water content decreasing
  - High volume substrate (other soils)
    - Can be confused with Stage 5: Tension restored (aeration at night)

5- The basics of irrigation: Stage 4
End of watering based on the type of greenhouse (joules)

Effect of the type of greenhouse on irrigation Conventional crop			
Tomato		Week: 25	
Type	1 or 2 100%	3 78.6%	4 68.8%
Actions			
End watering	150 J/cm²	191 J/cm²	218 J/cm²
No. hours BS	3:00	3:15	3:22
Actual time	5:41 p.m.	5:26 p.m.	5:19 p.m.

Effect of the type of greenhouse on irrigation Conventional crop			
Cucumber		Week: 25	
Type	1 or 2 100%	3 78.6%	4 68.8%
Actions			
End watering	100 J/cm²	127 J/cm²	145 J/cm²
No. hours BS	2:00	2:20	2:30
Actual time	6:41 p.m.	6:21 p.m.	6:11 p.m.

Effect of the type of greenhouse on irrigation Crop in soil (sandy loam)			
Tomato		Week: 25	
Type	1 or 2 100%	3 78.6%	4 68.8%
Actions			
End watering	1,200 J/cm²	1,527 J/cm²	1,744 J/cm²
No. hours BS	6:40	7:30	8:10
Actual time	2:01 p.m.	1:11 p.m.	12:31 p.m.

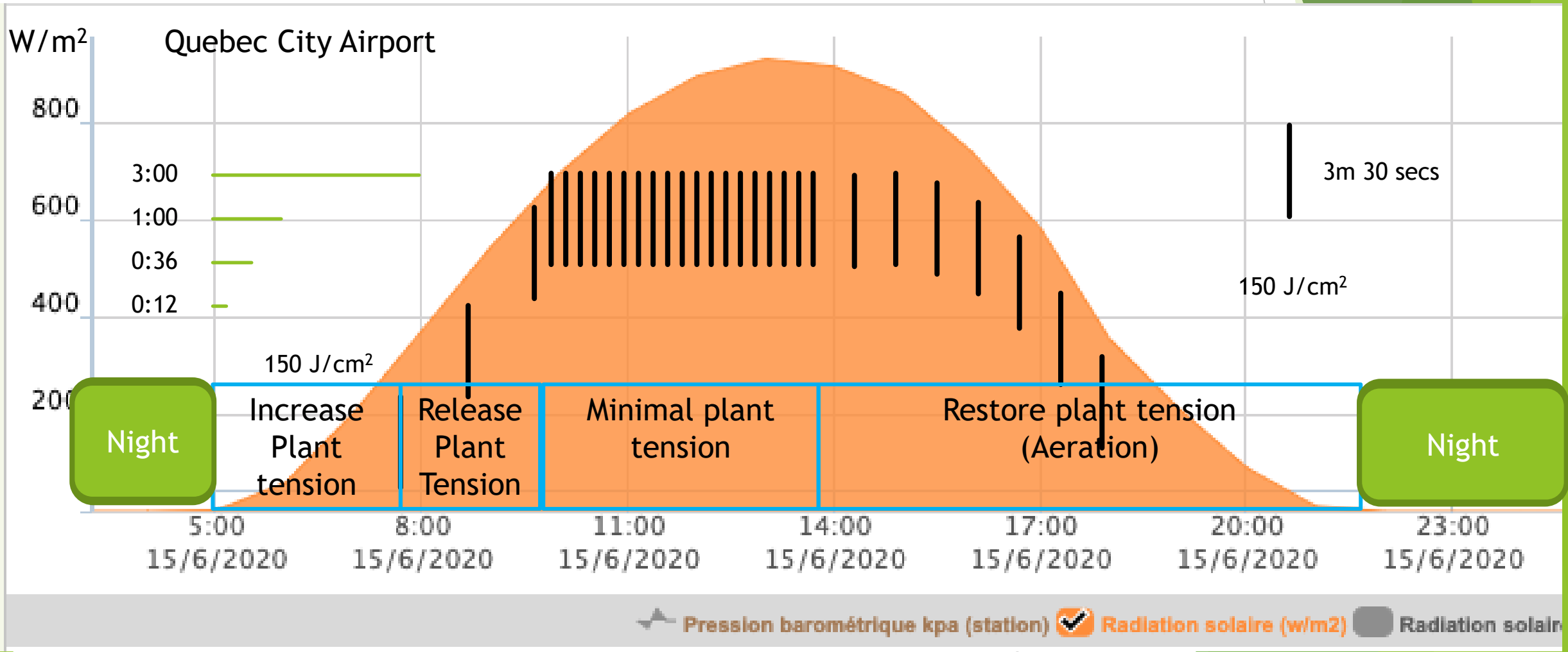
Effect of the type of greenhouse on irrigation Crop in soil (sandy loam)			
Cucumber		Week: 25	
Type	1 or 2 100%	3 78.6%	4 68.8%
Actions			
End watering	1,000 J/cm²	1272 J/cm²	1453 J/cm²
No. hours BS	6:10	6:55	7:30
Actual time	2:31 p.m.	1:46 p.m.	1:11 p.m.

Source : Climax Conseils

2 substrates X 2 crops X 3 types of greenhouse = 12 strategies

5- The basics of irrigation: Stage 5

Light curve, June 15, 2020 (week 25)



AgWeather Meteogram

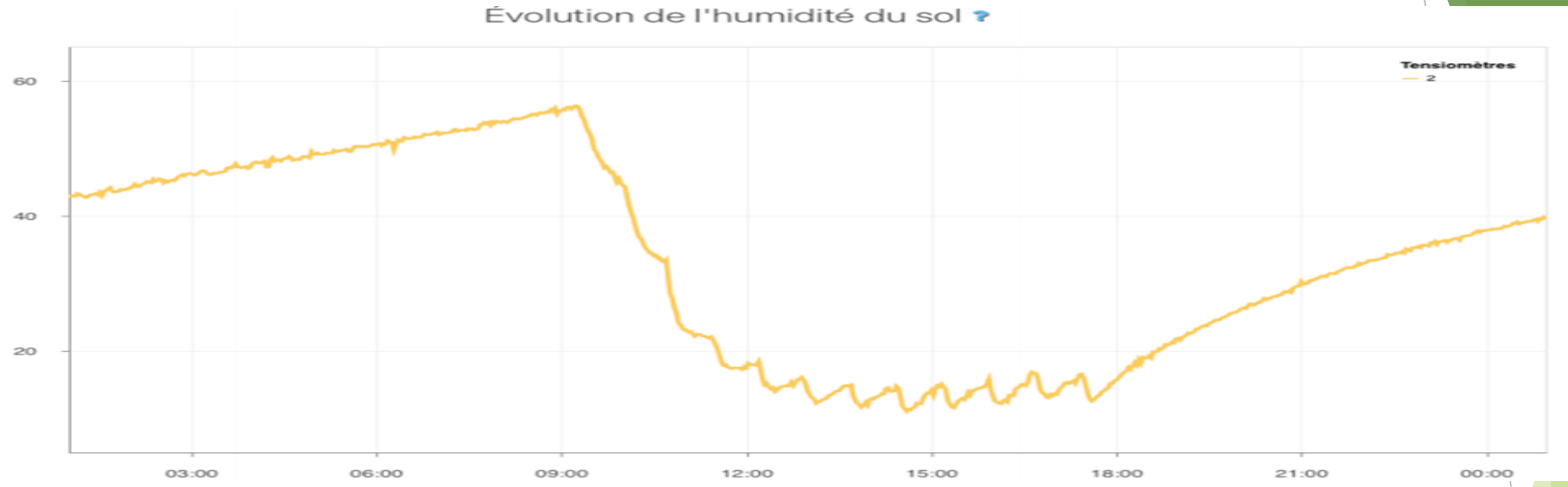
5- The basics of irrigation: Stage 5

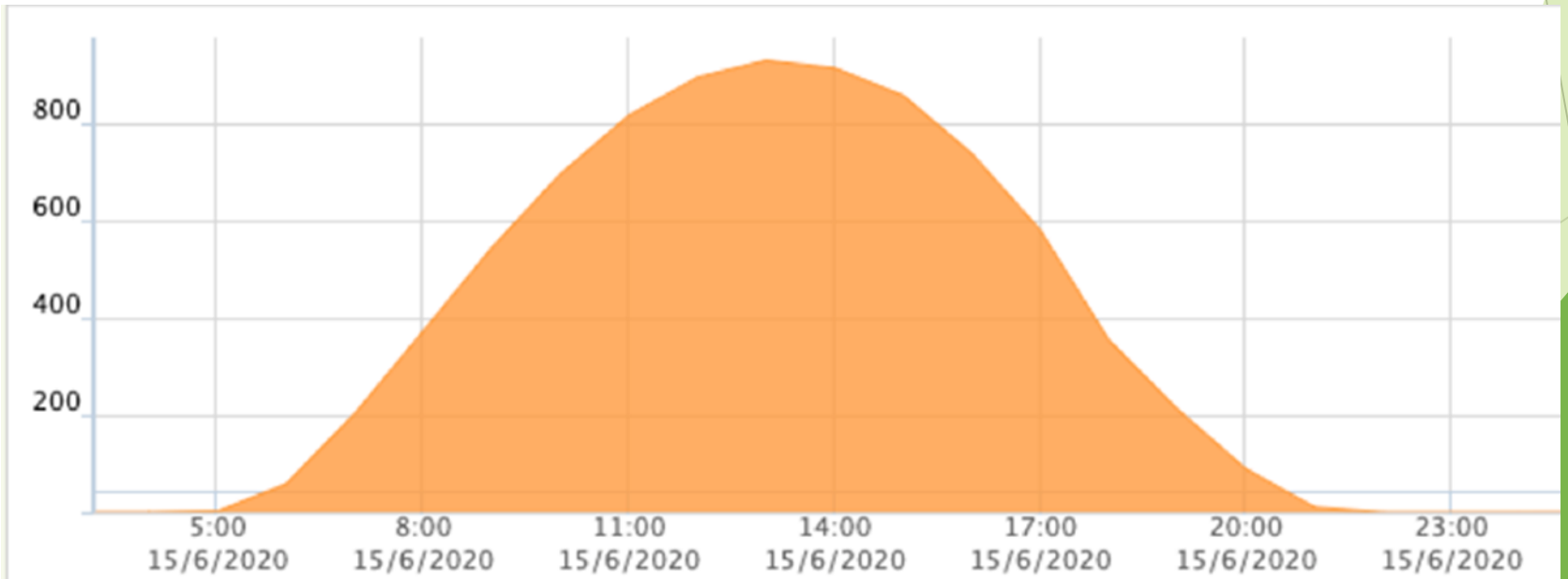
- Stage 5: Good night
  - Night is the longest period in watering management
    - Summer
      - Hydroponics = 12-14 hrs.
        - Watch for heat waves
          - Tomato: Consider watering 250 to 500 mL/m^2 at night following a heat wave
            - Half for cucumbers
      - Soil = 18 hrs or more
    - Winter
      - Hydroponics = 22 hrs.

A good night is the first commandment of irrigation management.

Valid water content of the substrate every morning before watering.

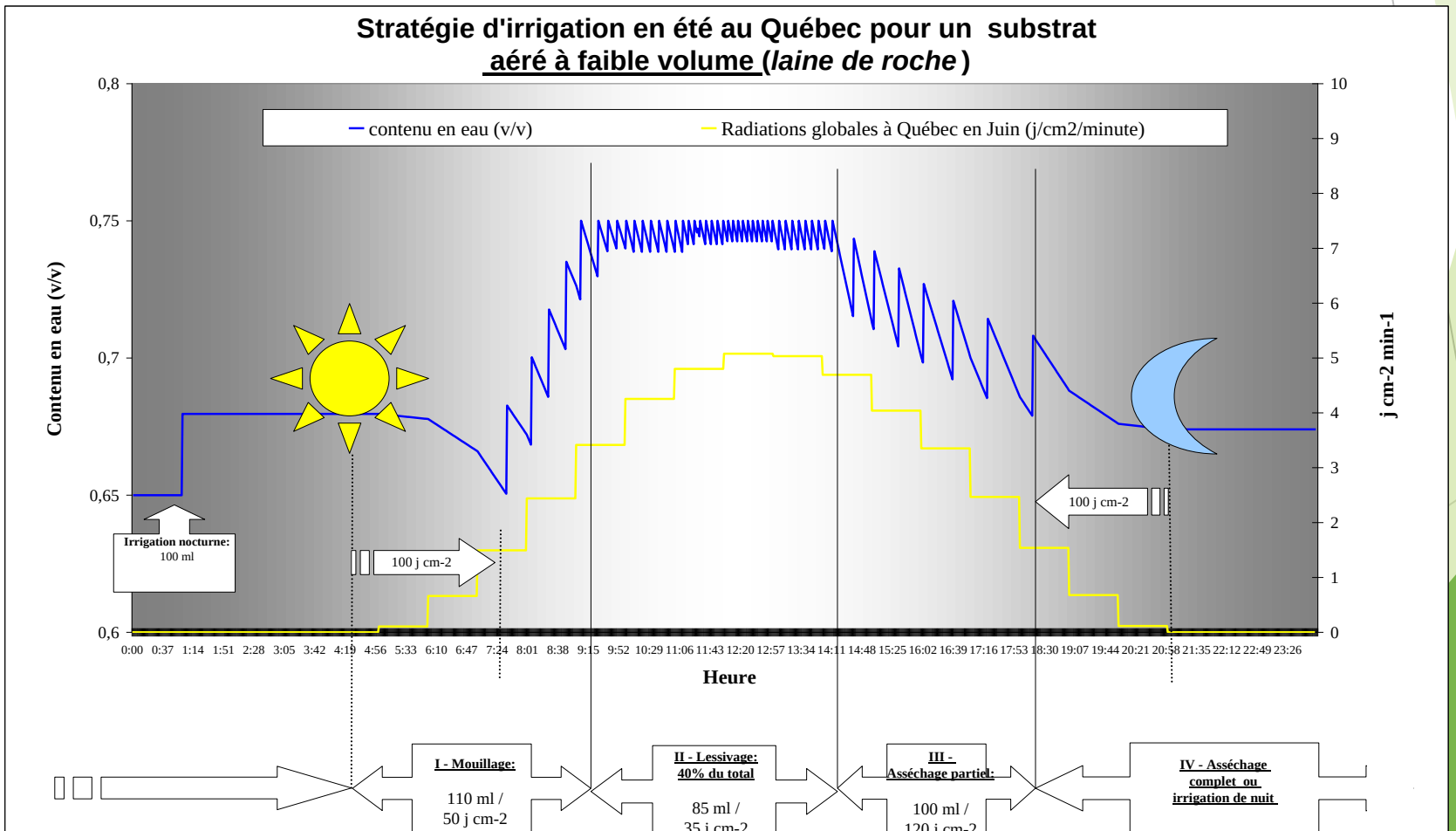
Understanding the water needs of crops





Understanding the water needs of crops

Irrigation in hydroponics for greenhouse vegetables: Marathon-style – up to 25-30 waterings/day



Source : Climax Conseils

Now that you know the speed of water uptake, you need to know how long it takes to dry (aeration).

- For a substrate, we examine two different volumes
  - 10 L/m^2 vs. 20 L/m^2
  - You want to dry (aerate) 3% between two waterings in peak periods.
    - 3% X 10 L = 300 mL
    - 3% X 20 L = 600 mL
  - If you have summer sun (1,000 w/m^2) with a type 2 greenhouse and a mature crop, what would your watering interval be?
    - 10 L:
    - 20 L:

Now that you know the speed of water uptake, you need to know how long it takes to dry (aeration).

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    - 3% X 10 L = 300 mL
    - 3% X 20 L = 600 mL
  - If you have summer sun (1,000 w/m^2) with a type 2 greenhouse and a mature crop, what would your watering interval be?
    - 10 L: 10 minutes
    - 20 L: 10 minutes

Irrigation

Available water vs. interval and volume strategy (the biggest day of the year):

The more water that is available, the less often we water (the more we let dry between two waterings)

Irrigation interval in peak period consumption (1,000 mL/m²/hr)								
Substrate			Irrigation interval					
Volume/m²	Available water		dripper/m²					
	100 %	5%						
(L)	(L)	(mL)	2	2.2	2.4	2.6	2.8	3
9	3.0	149	9	9	9	9	9	9
10	3.3	165	10	10	10	10	10	10
11	3.6	182	11	11	11	11	11	11
12	4.0	198	12	12	12	12	12	12
13	4.3	215	13	13	13	13	13	13
14	4.6	231	14	14	14	14	14	14
15	5.0	248	15	15	15	15	15	15
16	5.3	264	16	16	16	16	16	16

Volume/ irrigation/ trickler in peak period consumption (1,000 mL/m²/hr)								
Substrate			Irrigation interval					
Volume/m²	Available water		Dripper/m²					
	100 %	5%						
(L)	(L)	(mL)	2	2.2	2.4	2.6	2.8	3
9	3.0	149	149	135	124	114	106	99
10	3.3	165	165	150	138	127	118	110
11	3.6	182	182	165	151	140	130	121
12	4.0	198	198	180	165	152	141	132
13	4.3	215	215	195	179	165	153	143
14	4.6	231	231	210	193	178	165	154
15	5.0	248	248	225	206	190	177	165
16	5.3	264	264	240	220	203	189	176

Now that you know the speed of water uptake, you need to know how long it takes to dry (aeration).

- For a substrate, we examine two different volumes
  - 10 L/m^2 vs. 20 L/m^2
  - You want to dry (aerate) 10% of the volume of the substrate at night.
    - 10% X 10 L = 1,000 mL
    - 10% X 20 L = 2,000 mL
  - In a type 2 greenhouse with a mature crop, how many joules will you need between your last watering of the day and your first watering the next day?
    - 10 L:
    - 20 L:

Now that you know the speed of water uptake, you need to know how long it takes to dry (aeration).

- For a substrate, we examine two different volumes
  - 10 L/m^2 vs. 20 L/m^2
  - You want to dry (aerate) 10% of the volume of the substrate at night.
    - 10% X 10 L = 1,000 mL
    - 10% X 20 L = 2,000 mL
  - In a type 2 greenhouse with a mature crop, how many joules will you need between your last watering of the day and your first watering the next day?
    - 10 L: Tomato 300 J/cm^2 Cucumber 200 J/cm^2
    - 20 L: Tomato 300 J/cm^2 Cucumber 200 J/cm^2

Now that you know the speed of consumption, you need to know how long it takes to dry (aeration).

- How many joules will you need between your last watering and sunset?
  - 10 L:
  - 20 L:
- Estimate what time you should do your last watering. (see light graph)
  - 10 L:
  - 20 L:

Now that you know the speed of consumption, you need to know how long it takes to dry (aeration).

- How many joules will you need between your last watering and sunset?
  - 10 L: Tomato 150 J/cm^2 Cucumber 150 J/cm^2
  - 20 L: Tomato 150 J/cm^2 Cucumber 150 J/cm^2
- Estimate what time you should do your last watering. (see light graph)
  - 10 L: Tomato 5:41 pm Cucumber 6:41 pm
  - 20 L: Tomato 5:41 pm Cucumber 6:41 pm

What to remember

- Light is the main determiner for speed of water uptake
  - Stop thinking like clocks, start thinking like lights.
- The characteristics of the substrate determine the speed of drying (aeration).
- Substrate X light = drying intervals
  - Think as much to dry than to water

Very important

- Each volume of substrate must support the same light load = Uniformity
  - Spacing of wires
  - Spacing of heads
  - Volume of substrate/m^2 constant
  - 30% adjustment on the south, east and west rows
  - Adjustment to the number of drippers at the ends of the rows in hydroponics

6- Substrates characteristic and watering strategy

Water uptake before having 25% air

Impossible water uptake

Table 1 : Caracteristics of substrate water management

	Peat		Rock wool		Coconut fiber		Soil[1]		
	Wet	Aerated	75%	65%	Aerated	Wet	Sand	Sandy loam	Clay
Volume/m2 (liter)	20	20	9	9	13	15,6	60	70	80
% air à water holding capacity	15%	25%	20%	30%	30%	25%	25%	24%	9%
Air deficit at water holding capacity (%)	10%	0%	0%	0%	0%	0%	0%	1%	14%
Air deficit to restore (ml)	2000						0	700	11200
Water available (WA) (%)	35	25	35	30	27	33	4	10	13
Water available (WA) (mL)	7000	5000	3150	2700	3510	5148	2400	7000	10400
Vegetative interval (ml/m2) (5%WA)	350	250	157,5	135	175,5	257,4	240	700	1040
Generative interval (ml/m2) (10% WA)	700	500	315	270	351	514,8	480	1400	2080
Drip flow (L/hr)	6	4	4	2	3	4			
Peak flow (L/hr/m2)[2]	15	10	10	5	7,5	10			
Minimal water gift (min)	2	2	2	2	2	2	4	4	4
Minimal water gift (ml/m2)[2]	500	333	333	167	250	333			
Vegetative nigth drying (mL/m2) (7%)	1400	1400	630	630	910	1092	630	2000	?
Generative night drying (mL/m2) (12%)	2400	2400	1080	1080	1560	1872	1080	4000	?

1- Always generative interval because very low salt concentration effect

2- Estimated with 2.5 drippers/m2

Normal objective

6- Substrates characteristic and watering strategy

Breakdown of watering volumes by period

- 1- Enter the basic parameters

Basic parameter	
Water uptake (ml/joule)	2
Runoff	30%
Night drying (mL/m^2)	1225
Peak interval (ml/m2)	289
Peak interval (joules/cm2)	144,5

289 mL/2 mL/joule

Producer's objective

Field validation

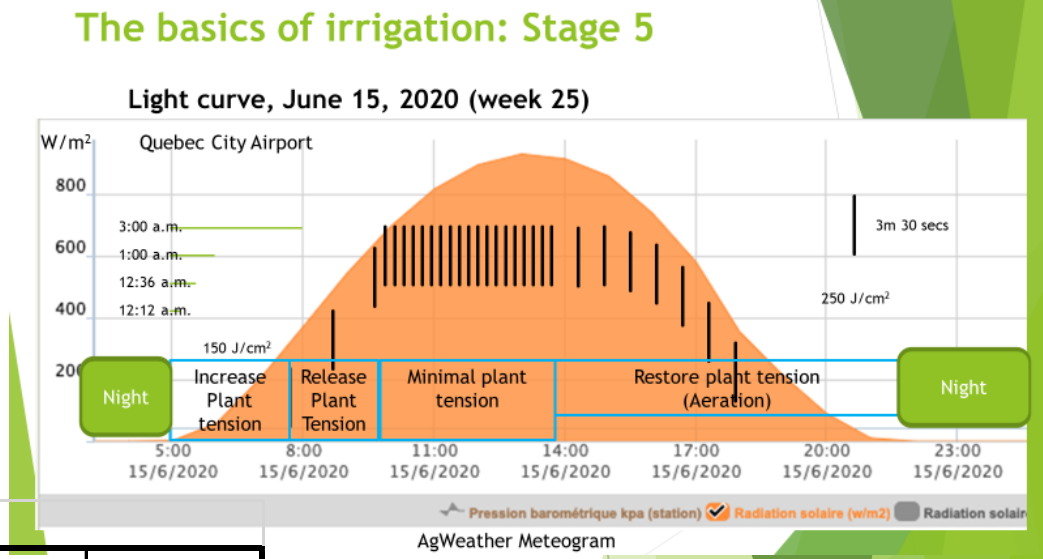
Tableau 4 : Caractéristiques d'irrigation des substrats par m²				
	Unités	Coco	Tourbe	Laine de roche
		Natural	aéré	75%
Volume	litre/m²	17,5	20	9
% air	%	22%	25%	20%
Eau (RFU) (%)	%	33	33	66
RFU	ml	5 775	6 600	5 940
Intervalle végétatif (5%RFU)	ml	289	330	297
Intervalle reproductif (10%RFU)	ml	578	660	594
Débit au goutteur	l/hr	4	6	2
Assèchement. de nuit véget (7% vol.tot)	ml	1 225	1 400	630
Assèchement de nuit reprod (12%)	ml	2 100	2 400	1 080

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in hydroponics

- 2- Establish water uptake for the crop by period based on your graphical analysis
  - Joules/m²/period X mL/m²/joule
  - Add runoff for the peak period



Water uptake

Period	Light (Joule/cm2)	water uptake (mL/m2)	Runoff (mL/m2)	Total (mL/m2)
Total	2875	5750		5750
Total night drying (1 + 4 + night)		-1225		-1225
Release plant tension (2)	326	652		652
Minimal plant tension (3)	1584	3168	2464,29	5632,29
End of minimal plant tension till end of watering (4)	800	1600		1600
End of watering till night (4)	150	300		300
Night		0		0
Increase plant tension (1)	150	300		300
Total	3010	6020		
(Number = irrigation stage)				

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in hydroponics

- 3- Determine the input volumes by period
  - 1- Manage drying at night (line A) : Total uptake between the end of minimal plant tension stage and the end of increase plant tension stage (stage 4-5-1, lines D-E-F-G) – total night drying (line A)

Period	Total (mL/m2)		Watering strategy: Water gift per period							
			A	B	C	D	E	F	G	Total
Total	5750									
Total night drying (1 + 4 + night)	-1225	A								0
Release plant tension (2)	652	B	1225	652						1877
Minimal plant tension (3)	5632,29	C			5632,28571					5632,28571
End of minimal plant tension till end of watering (4)	1600	D	-1225			1600	300		300	975
End of watering till night (4)	300	E								0
Night	0	F						0		0
Increase plant tension (1)	300	G								0
Total										8484,28571
									Runoff	2464,28571
(Number = irrigation stage)									Water uptake	6020

6- Substrates characteristic and watering strategy

Management of water volumes in hydroponics

- 3- Determine the input volumes by period
  - Manage release plant tension
    - Water uptake during release plant tension (stage 2, line B) + total night drying (we dried, now we must moisten)

Period	Total (mL/m2)		Watering strategy: Water gift per period							
Total	5750		A	B	C	D	E	F	G	Total
Total night drying (1 + 4 + night)	-1225	A								0
Release plant tension (2)	652	B	1225	652						1877
Minimal plant tension (3)	5632,29	C			5632,28571					5632,28571
End of minimal plant tension till end of watering (4)	1600	D	-1225			1600	300		300	975
End of watering till night (4)	300	E								0
Night	0	F						0		0
Increase plant tension (1)	300	G								0
Total										8484,28571
									Runoff	2464,28571
(Number = irrigation stage)									Water uptake	6020

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in hydroponics

- 3- Determine the input volumes
  - Manage the minimal plant tension (stage 3 = line C)
    - Provide water uptake + Runoff

Period	Total (mL/m2)		Watering strategy: Water gift per period							
Total	5750		A	B	C	D	E	F	G	Total
Total night drying (1 + 4 + night)	-1225	A								0
Release plant tension (2)	652	B	1225	652						1877
Minimal plant tension (3)	5632,29	C			5632,28571					5632,28571
End of minimal plant tension till end of watering (4)	1600	D	-1225			1600	300		300	975
End of watering till night (4)	300	E								0
Night	0	F						0		0
Increase plant tension (1)	300	G								0
Total										8484,28571
									Runoff	2464,28571
(Number = irrigation stage)									Water uptake	6020

Check that it balances

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in hydroponics

- 4- Determine the intervals and volumes by watering
  - Release plant tension (stage 2, line B)
    - 3 waterings in 2 hr = 60 minutes interval
    - Equal distribution of volumes by watering

Water uptake			Watering strategy				
Period	Total (mL/m2)		ter gift per pe	Interval		Nb watering	Vol/gift
			Total	Minutes	Joules		(mL/m2)
Total	5750						
Total night drying (1 + 4 + night)	-1225	A	0				
Release plant tension (2)	652	B	1877	60		3	625,666667
Minimal plant tension (3)	5632,29	C	5632,28571		144,5	10,96	513,803842
End of minimal plant tension till end of watering (4)	1600	D	975		237,128205	3,373702422	289
End of watering till night (4)	300	E	0				
Night	0	F	0				
Increase plant tension (1)	300	G	0				
Total			8484,28571				
			2464,28571				
(Number = irrigation stage)			6020				

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in hydroponics

- 4- Determine the intervals and volumes by watering
  - Minimal plant tension (Peak period) (stage 3, line C)
    - Indicate your peak interval (joules/cm^2)

Basic parameter	
Water uptake (ml/joule)	2
Runoff	30%
Night drying (mL/m^2)	1225
Peak interval (ml/m2)	289
Peak interval (joules/cm2)	144,5

Water uptake			Watering strategy				
Period	Total (mL/m2)		ter gift per pe	Interval		Nb watering	Vol/gift
			Total	Minutes	Joules		(mL/m2)
Total	5750						
Total night drying (1 + 4 + night)	-1225	A	0				
Release plant tension (2)	652	B	1877	60		3	625,666667
Minimal plant tension (3)	5632,29	C	5632,28571		144,5	10,96	513,803842
End of minimal plant tension till end of watering (4)	1600	D	975		237,128205	3,373702422	289
End of watering till night (4)	300	E	0				
Night	0	F	0				
Increase plant tension (1)	300	G	0				
Total			8484,28571				
			2464,28571				
(Number = irrigation stage)			6020				

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in hydroponics

- 4- Determine the intervals and volumes by watering
  - Minimum plant tension
    - Determine the number of waterings: total joules/peak interval = 1,584/144,5 = 10.96
    - Determine your volume of watering by irrigation: 5,632/10.96 = 513.8 mL

Water uptake

Period	Light (Joule/cm2)		Watering strategy: ter gift per pe Total	Interval Minutes	Interval Joules	Nb watering	Vol/gift (mL/m2)
Total	2875						
Total night drying (1 + 4 + night)		A	0				
Release plant tension (2)	326	B	1877	60		3	625,666667
Minimal plant tension (3)	1584	C	5632,28571		144,5	10,96	513,803842
End of minimal plant tension till end of watering (4)	800	D	975		237,128205	3,373702422	289
End of watering till night (4)	150	E	0				
Night		F	0				
Increase plant tension (1)	150	G	0				
Total	3010		8484,28571				
			2464,28571				
(Number = irrigation stage)			6020				

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in hydroponics

- 4- Determine the intervals and volumes by watering
  - End of peak at end of watering
    - Determine your interval in joules aiming for regular drying; extend the interval
      - Water uptake/water gift X peak interval

      = 1,600/975 X 144.5 = 237.13 joules

Water uptake				Watering strategy				
Period	Light (Joule/cm2)	water uptake (mL/m2)		ter gift per pe	Interval		Nb watering	Vol/gift
Total	2875	5750		Total	Minutes	Joules		(mL/m2)
Total night drying (1 + 4 + night)		-1225	A	0				
Release plant tension (2)	326	652	B	1877	60		3	625,666667
Minimal plant tension (3)	1584	3168	C	5632,28571		144,5	10,96	513,803842
End of minimal plant tension till end of watering (4)	800	1600	D	975		237,128205	3,373702422	289
End of watering till night (4)	150	300	E	0				
Night		0	F	0				
Increase plant tension (1)	150	300	G	0				
Total	3010	6020		8484,28571				
				2464,28571				
(Number = irrigation stage)				6020				

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in hydroponics

- 4- Determine the intervals and volumes by watering
  - Restore plant tension (stage 4, line D)
    - Determine your volumes by watering
      - Total volume/number of waterings = 975 mL/3.37 = 289 mL

Water uptake				Watering strategy				
Period	Light (Joule/cm2)	water uptake (mL/m2)		ter gift per pe	Interval		Nb watering	Vol/gift
Total	2875	5750		Total	Minutes	Joules		(mL/m2)
Total night drying (1 + 4 + night)		-1225	A	0				
Release plant tension (2)	326	652	B	1877	60		3	625,666667
Minimal plant tension (3)	1584	3168	C	5632,28571		144,5	10,96	513,803842
End of minimal plant tension till end of watering (4)	800	1600	D	975		237,128205	3,373702422	289
End of watering till night (4)	150	300	E	0				
Night		0	F	0				
Increase plant tension (1)	150	300	G	0				
Total	3010	6020		8484,28571				
				2464,28571				
(Number = irrigation stage)				6020				

Source : Climax Conseils

What happens if you have a cloudy day (35%)?

1- Enter your new light data and your leaching.
2- Check that you do not obtain negative data in the volumes to be gift, in which case you should borrow joules from previous periods.
280 – 65/2 = 247.5.

Basic parameter	
Water uptake (ml/joule)	2
Runoff	10%
Night drying (mL/m^2)	1225
Peak interval (ml/m2)	289
Peak interval (joules/cm2)	144,5

Period	Light (Joule/cm2)	water uptake (mL/m2)	Runoff (mL/m2)	Total (mL/m2)
Total	1006	2012		2012
Total night drying (1 + 4 + night)		1225		1225
Release plant tension (2)	114	228		228
Minimal plant tension (3)	554	1108	223,555556	1331,55556
End of minimal plant tension till end	280	560		560
End of watering till night (4)	150	300		300
Night		0		0
Increase plant tension (1)	150	300		300
Total	1248	2496		2719,55556

(Number = irrigation stage)

Watering strategy

Water gift per period								Interval		Nb watering	Vol/gift
A	B	C	D	E	F	G	Total	Minutes	Joules		(mL/m2)
							0				
1225	228						1453	60		3	484,333333
		1331,55556					1331,55556		144,5	3,83	347,310068
-1225			560	300	0	300	-65		-1244,92308	-0,224913495	289
							0				
					0		0				
							0				
							2719,55556				
						Runoff	223,555556				
						Water uptake	2496				

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in soil

- 1- Proceed at first as with hydroponics.

Basic parameter		Comments
Water uptake (ml/joule)	2	Fied validation
Runoff	5%	Related to CE and uniformity
Night drying (mL/m^2)	2400	Maximum tension between 4 and 6 kPa
Peak interval (ml/m2)	1200	5 à 10% WA
Peak interval (joules/cm2)	600	

Water uptake

Period	Light (Joule/cm2)	water uptake (mL/m2)	Runoff (mL/m2)	Total (mL/m2)
Total	2875	5750		5750
Total night drying (1 + 4 + night)		2400		2400
Release plant tension (2)	326	652		652
Minimal plant tension (3)	1584	3168	302,631579	3470,63158
End of minimal plant tension till end	800	1600		1600
End of watering till night (4)	150	300		300
Night		0		0
Increase plant tension (1)	150	300		300
Total	3010	6020		

(Number = irrigation stage)

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in soil

- 2- We monitor the negative values and borrow from previous periods (e.g., sunny day).
  - 200 mL must therefore be deducted from period C (stage 3)

Watering strategy

Water gift per period								Interval		Nb watering	Vol/gift
A	B	C	D	E	F	G	Total	Minutes	Joules		(mL/m2)
							0				
2400	652						3052	60		3	1017,33333
		3470,63158					3470,63158		600	2,64	1314,63317
-2400			1600	300	0	300	-200		-4800	-0,166666667	1200
							0				
					0		0				
							0				
							6322,63158				
						Runoff	302,631579				
						Water uptake	6020				

Source : Climax Conseils

6- Substrates characteristic and watering strategy

Management of water volumes in soil

- We monitor the negative values and borrow from previous periods (e.g., cloudy day = 35%).
- The peak period (stage 3 line C) must even be completely eliminated and part of the release plant tension (stage 2 line B) must be deducted to result in only 2,496 mL.

Watering strategy

Water gift per period								Interval		Nb watering	Vol/gift
A	B	C	D	E	F	G	Total	Minutes	Joules		(mL/m2)
							0				
2400	228						2628	60		3	876
		1108					1108		600	0,92	1200
-2400			560	300	0	300	-1240		-270,967742	-1,033333333	1200
							0				
					0		0				
							0				
							2496				
						Run off	0				
						Water uptake	2496				

Source : Climax Conseils

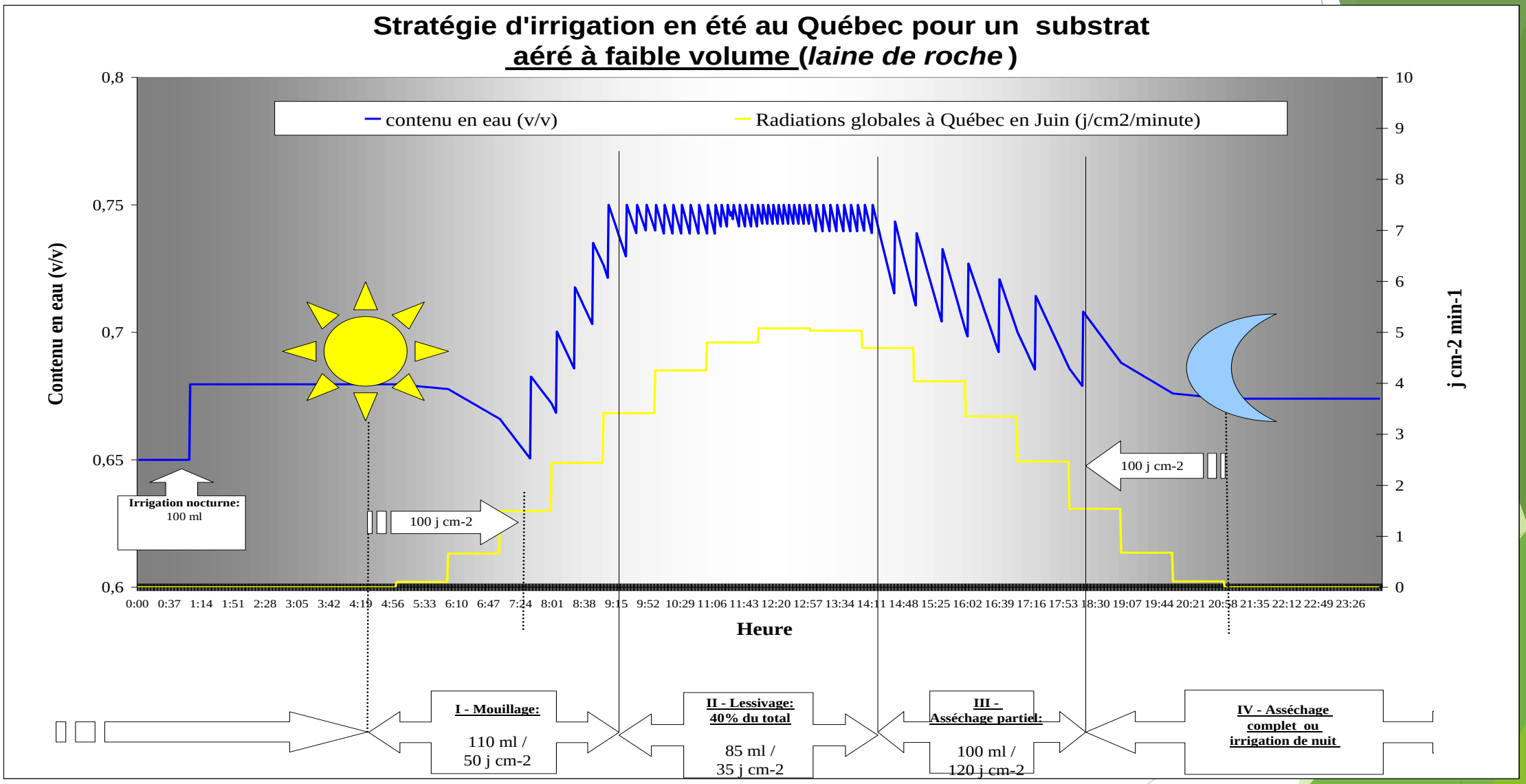
Most important

- Ensure drying at night.

THE BEST IRRIGATION MANAGER IS ONE WHO GETS HIS OR HER HANDS DIRTY EVERY MORNING BEFORE THE FIRST WATERING.

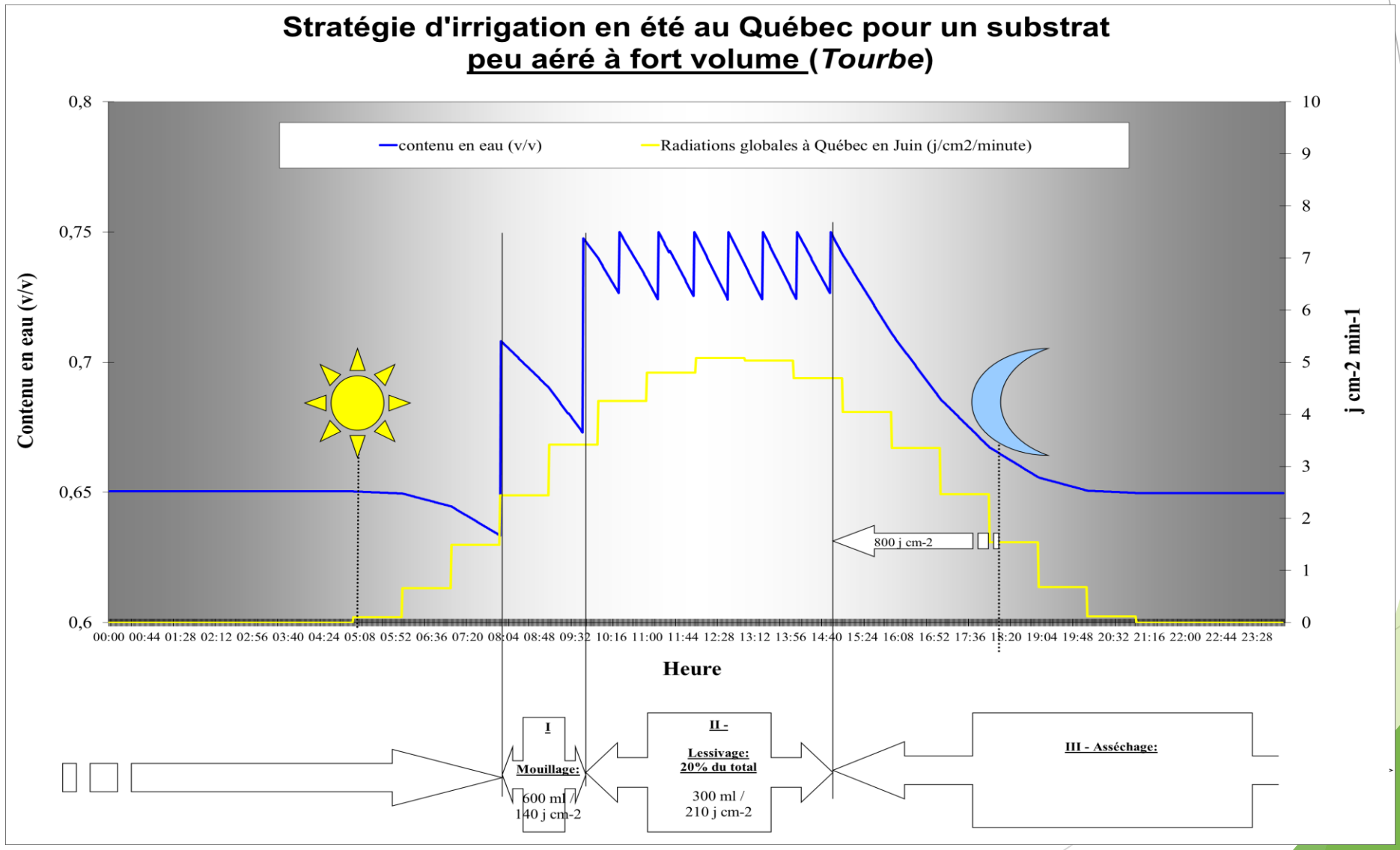
7- Some examples of watering strategies.

Daily profile: Rock wool water content



Source : Climax Conseils

Daily profile: Wet peat water content



Source : Climax Conseils

Full soil

Example of an irrigation system in sandy soil

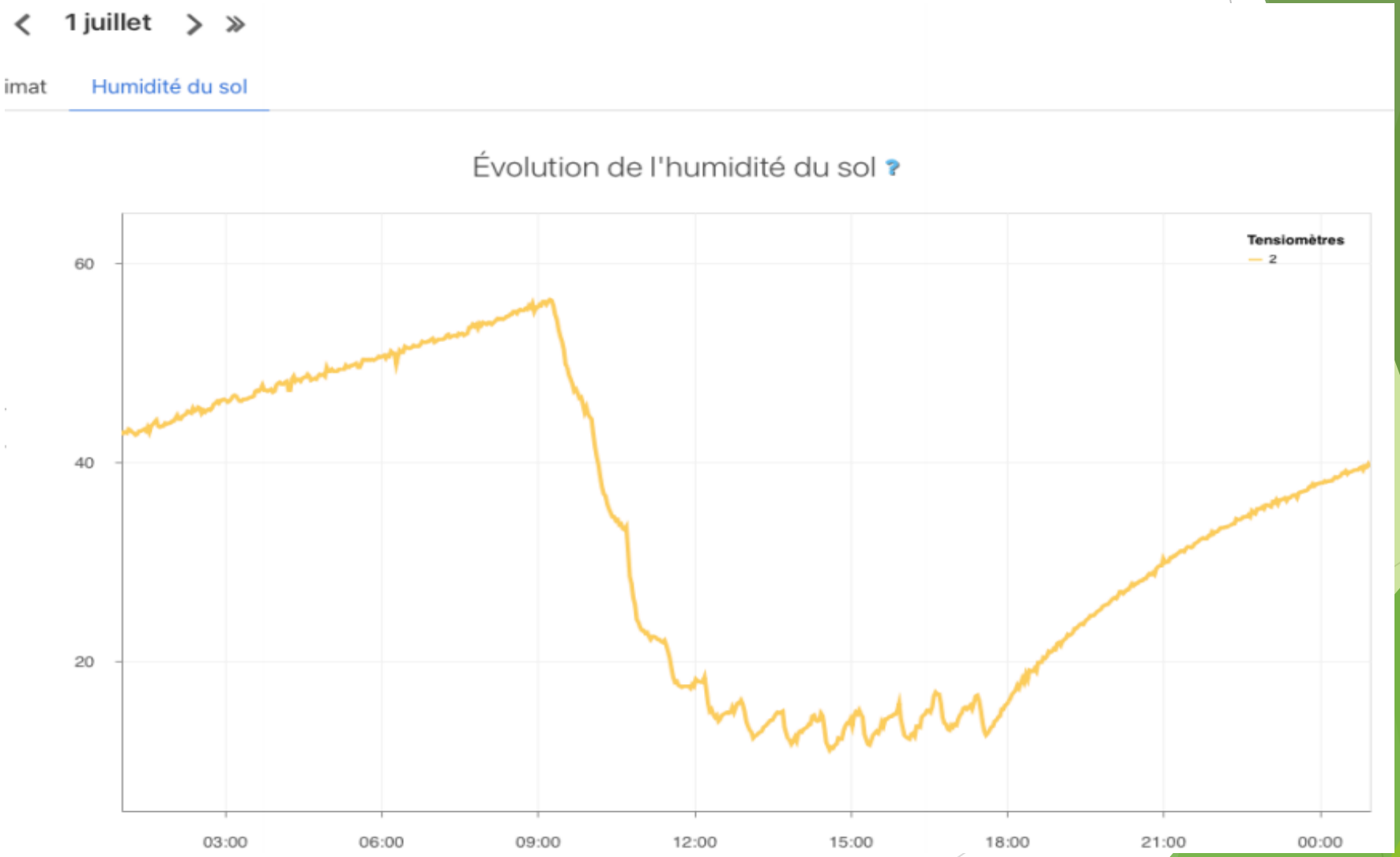
Eau à donner en terme de minutes

Heure	Durée	Heure	Durée	Heure	Durée
08:00	4				
08:45	4	08:45	4	08:45	4
09:30	4	09:30	4		
10:15	4	10:15	4	10:15	4
10:45	4	10:45	4		
11:15	4				
11:45	4	11:45	4	11:45	4
12:15	4	12:15	4		
12:45	4				
13:15	4	13:15	4	13:15	4
14:45	4	14:45	4		
17:30	4				
Total	**48**	**Total**	**32**	**Total**	**16**

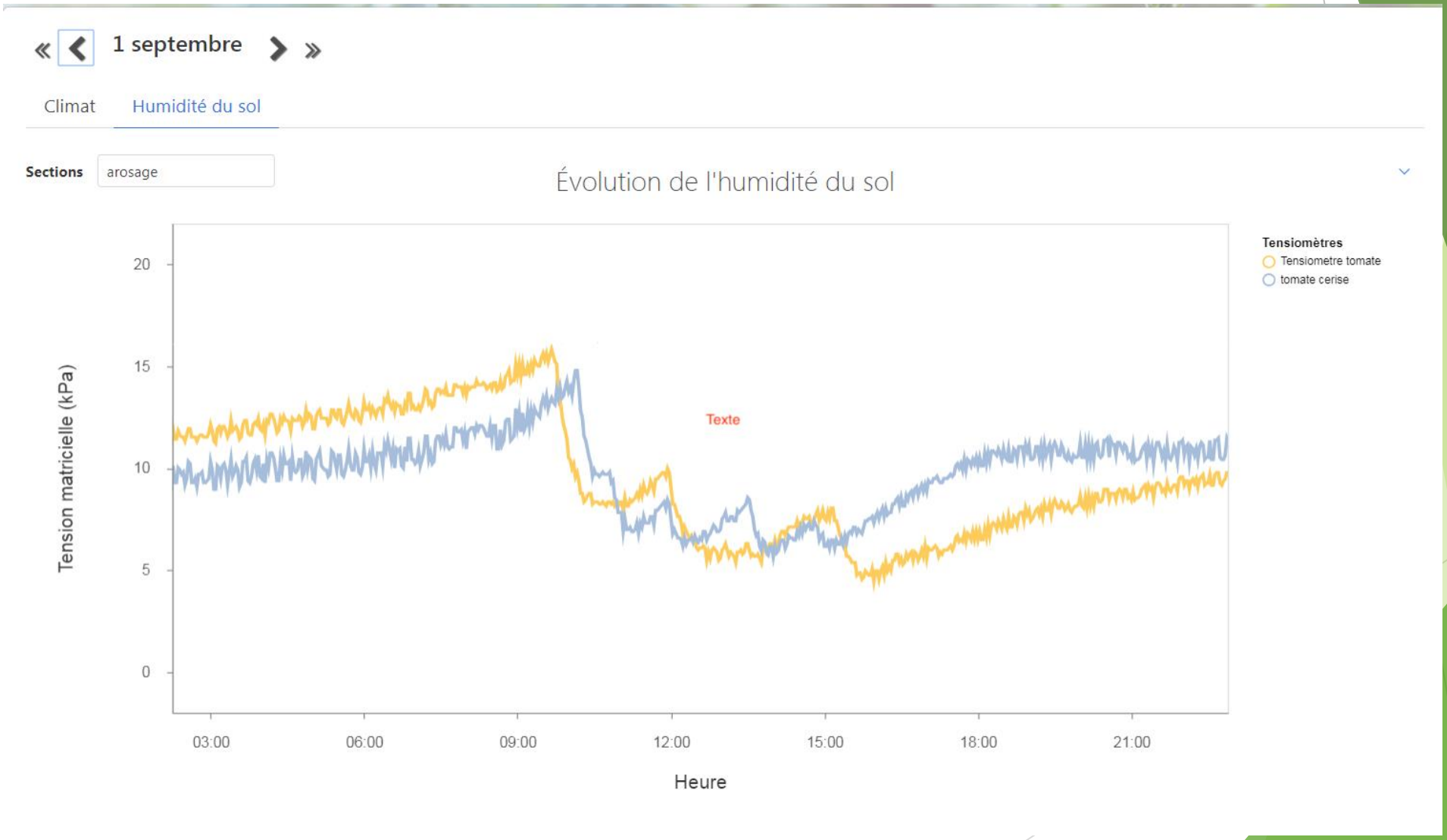
Programmation	A	B	C
Combinaisons	A+B+C	B+C	C

Source : Climax Conseils

Tension curve – Sandy soil (mb=0.1 kPa)



Tension curve



Thank You

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CONSEILS