Irrigation and Drainage Engineering

(Soil Water Regime Management)

(ENV-549, A.Y. 2025-26)

4ETCS, Master option

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Platform of Hydraulic Constructions

Lecture 7-1. Sprinkler irrigation: spraying and frost fighting

Sprinkler systems

- Spray booms
- rotating systems (low and medium pressure sprinklers, watering cannons)
- watering machines (high pressure sprinklers, self-propelled cannon, central pivot, straight booms, etc.)

Criteria for choosing a sprinkler

- quantity of water to be supplied
- rainfall to be respected and desired uniformity
- available pressure
- nature of the soil and type of vegetation
- Wind statistics
- shape and size of plots
- special conditions (frost protection, etc.)
- cost

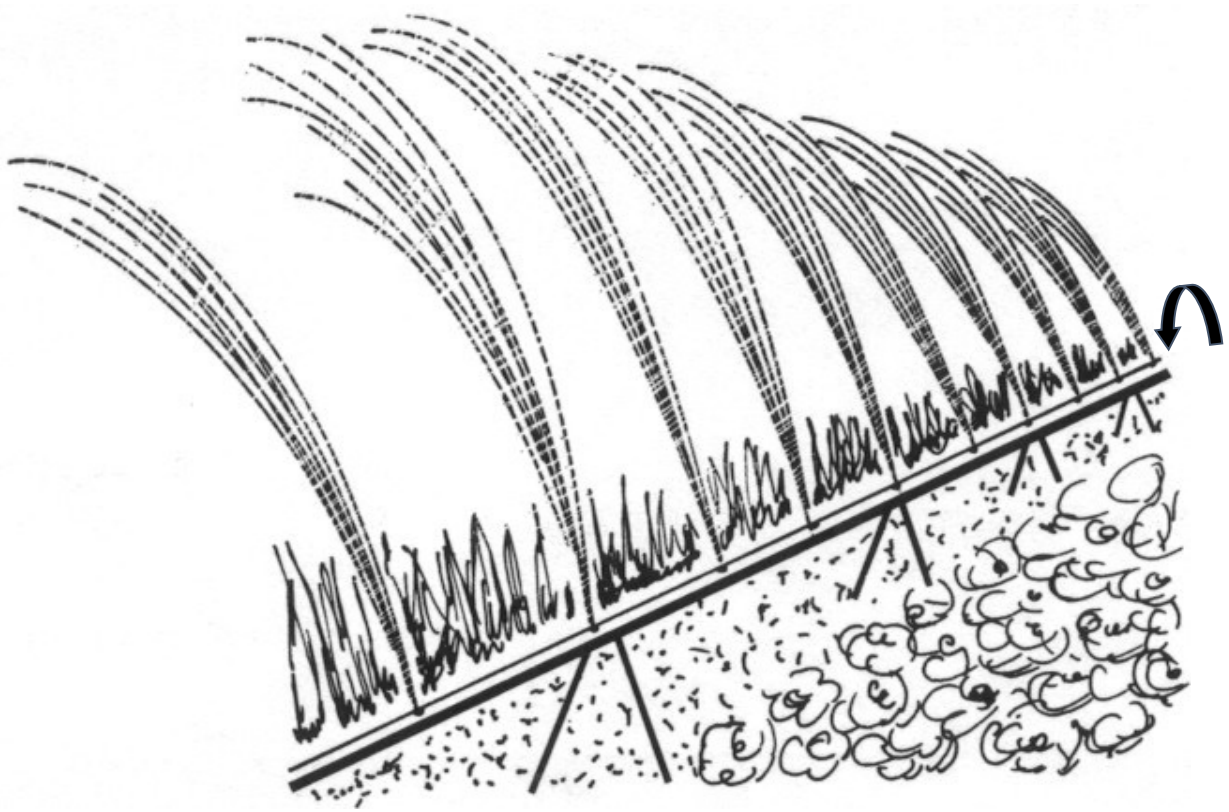
Maximal spraying (max pluviometry)

The max pluviometry should always be less than the soil infiltration capacity. Indicative values for a range of soils are as follows

Max pluviometry expressed in mm/h for different soil types and slopes

Type de sol	Pente : 0 – 10 %		Pente : > 10 %	
	Couvert	Nu	Couvert	Nu
Sols sableux	50	25	25	15
Sols sablo-silteux	25	15	15	10
Sols silto-sableux	15	10	10	5
Sols argileux	4	2	2	2

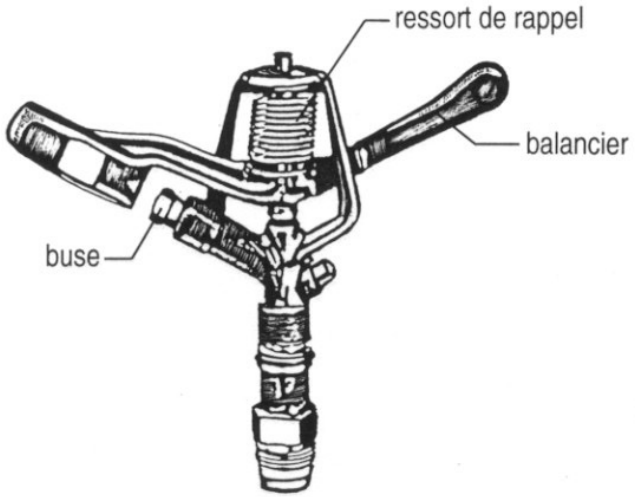
Spray booms

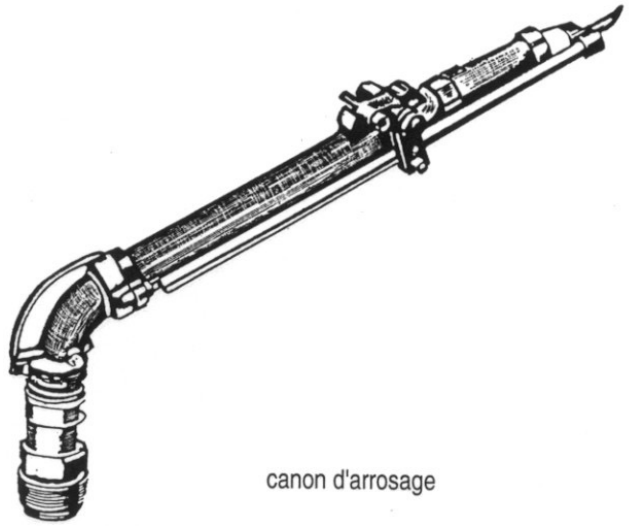


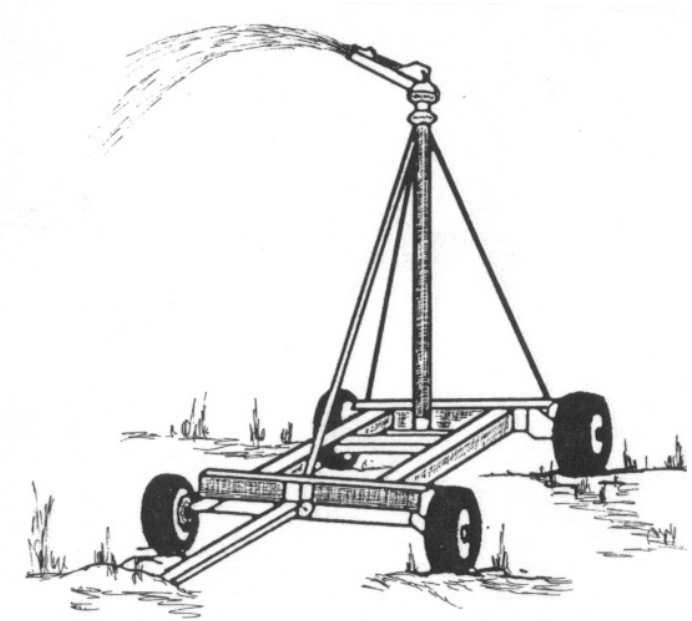
- Low pressure (0.5 - 2 bar)
- Short range (5 - 10 m)
- High rainfall (10 - 50 mm/h)

The pluviometry is relativley high given the low technology associated to this technique. Hence, use is limited to short durations and soils with good infiltration capacity

Rotating systems







Medium pressure (sprinkler)

- P : 2 to 5 bars
- R* : 10 tp 20 m
- i : 2 to 15 mm/h
- Q : 0.5 to 8 m^3/h

High pressure (water cannon/gun)

- P : up to 8 bars
- R* : up to 65 m and more
- i : 8 to 25 mm/h
- Q : 10 to 100 m^3/h

Trolley-mounted cannon/gun

* Distance range; low pressure sprinklers (1-2 bars) cover a maximal range of 5-10 m

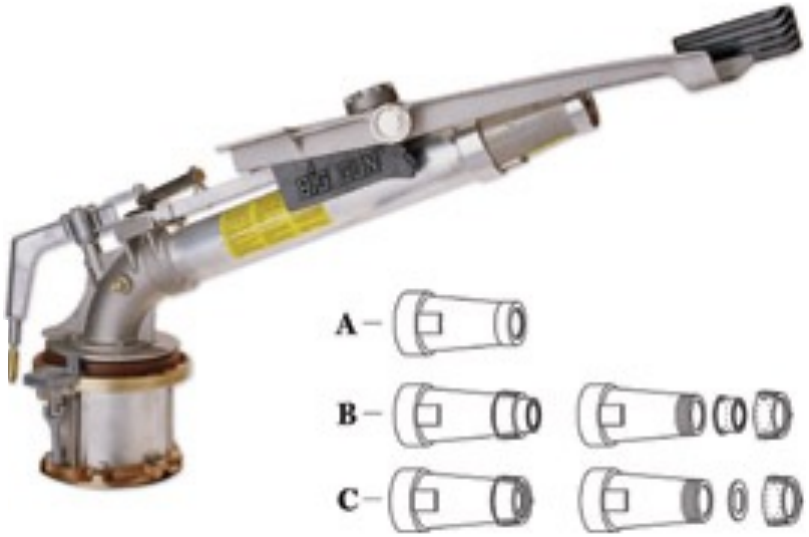
Characteristics of a sprinkler

- Pressure P
- Flow Q and current i
- Reach R
- Uniformity
- Rotation speed

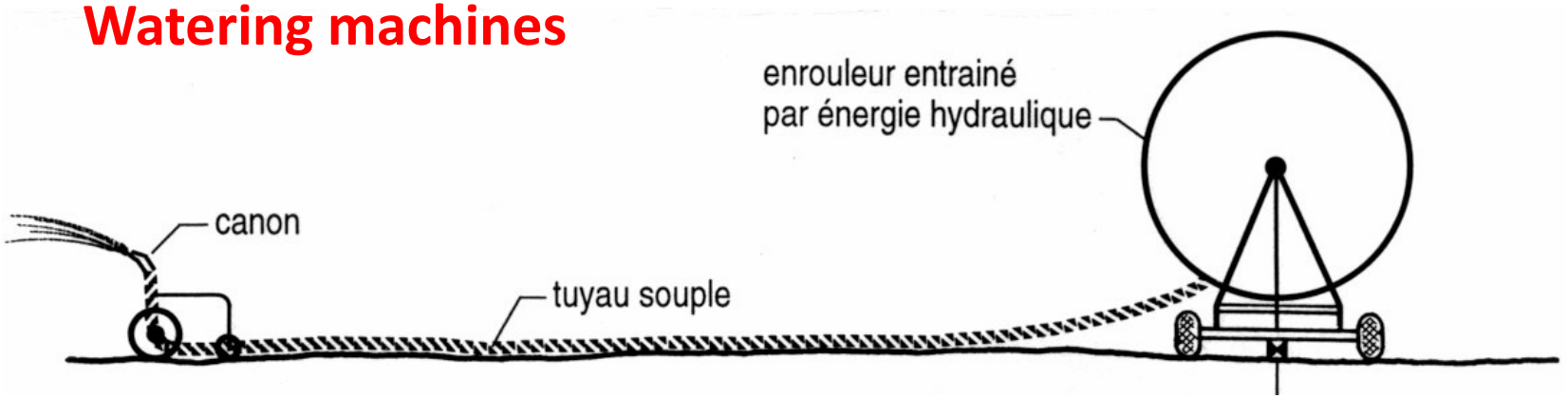
Medium-pressure sprinklers

High pressure

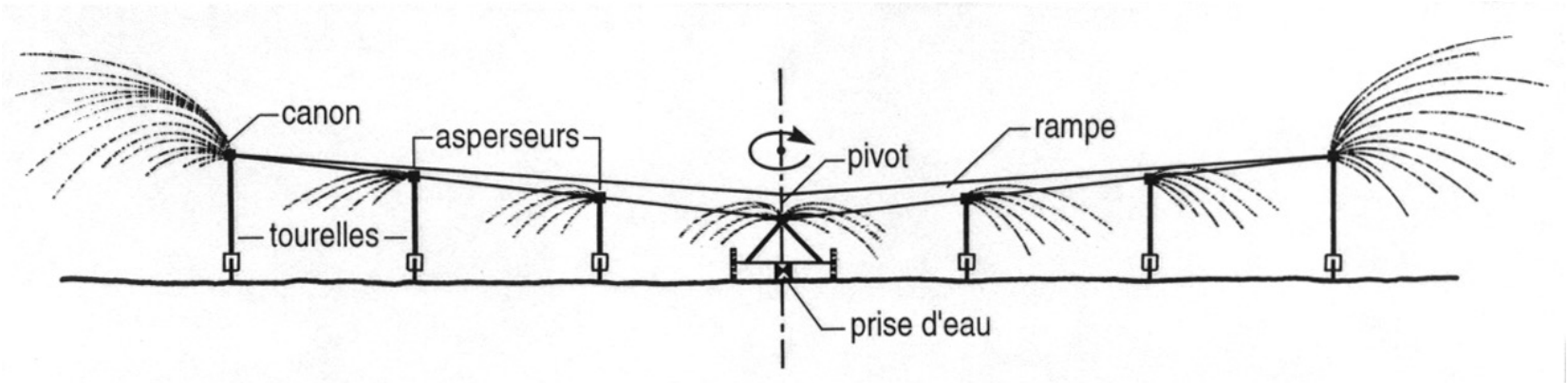
(spray cannon/gun)



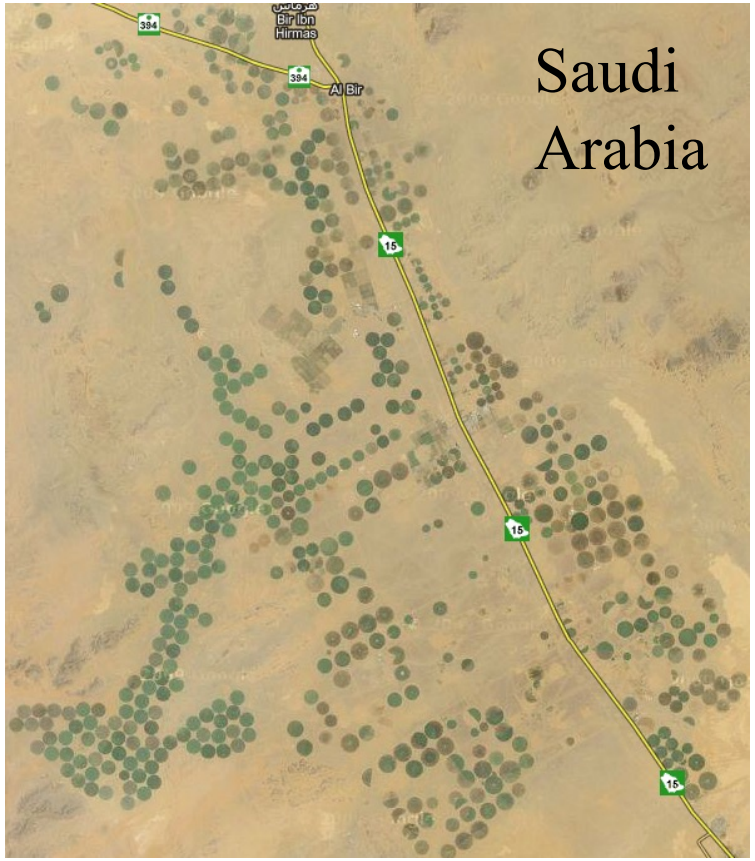
Watering machines

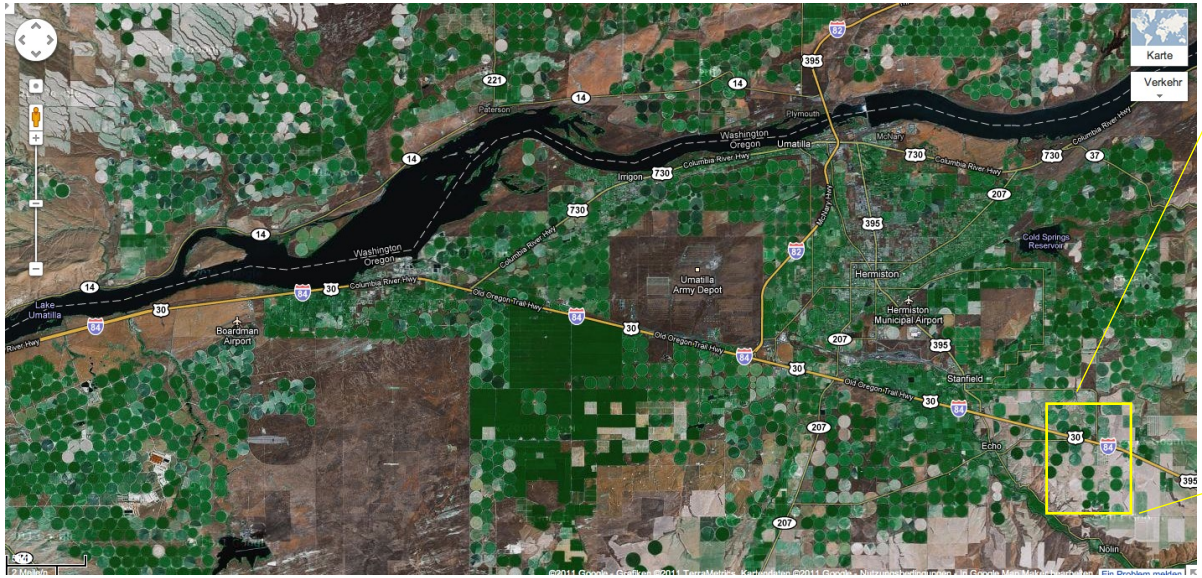


Self-propelled gun pulled by the feed pipe



Central Pivot (hydraulic motor)





Washington State,
USA

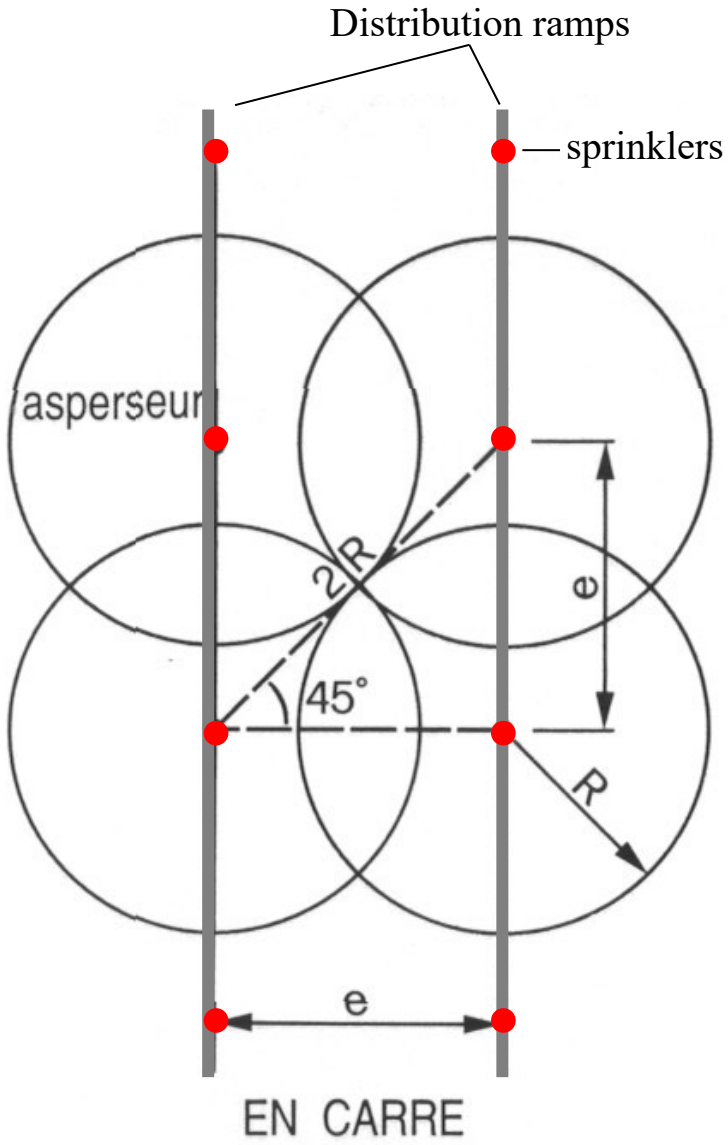
Sprinkler layout geometry

Overlapping Square deployment

$e = 2\ R \cos 45^{o} \cong 0.7\ D$

In practice: $e \cong 0.65\ D$

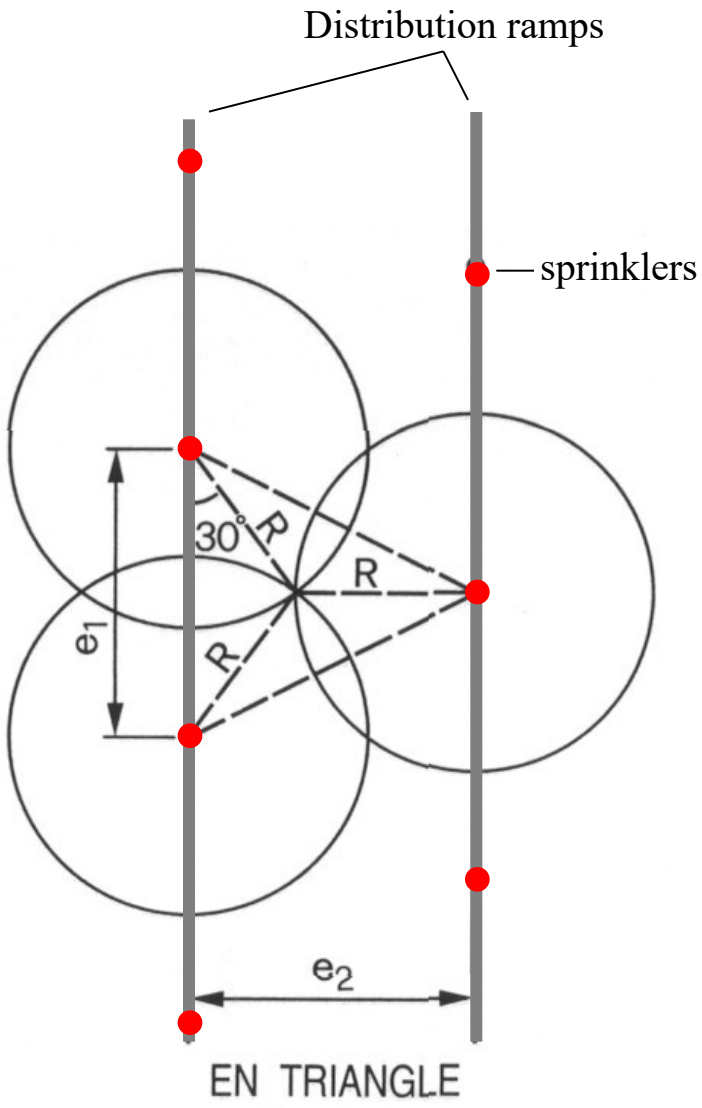
This is to ensure a good coverage



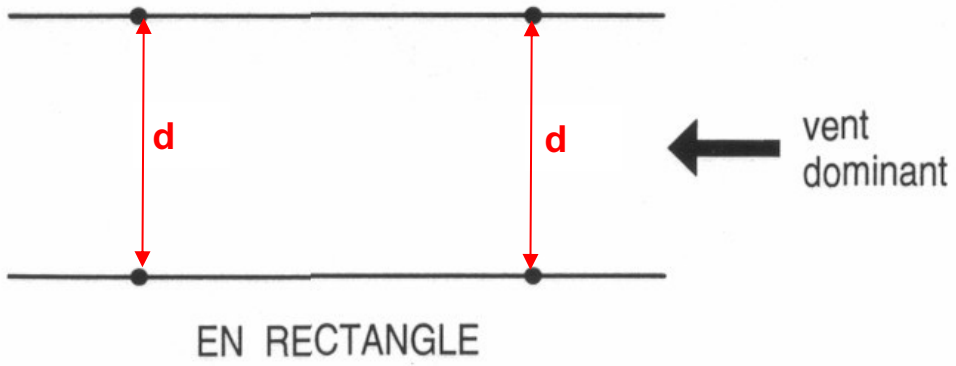
Overlapping Triangular deployment

$e_1 = 2\ R \cos 30^o$

$e_2 = R + R \sin 30^o = 1.5\ R$



Rectangular deployment



Frequently used under prevailing winds conditions. In this case, the distance d between the ramps parallel to the prevailing wind direction should not exceed:

- 50 to 60% of the diameter of the ground spot for winds between 0 and 8 km/h
- 40 to 50% for winds between 8 and 16 km/h
- 30% for winds above 16 km/h

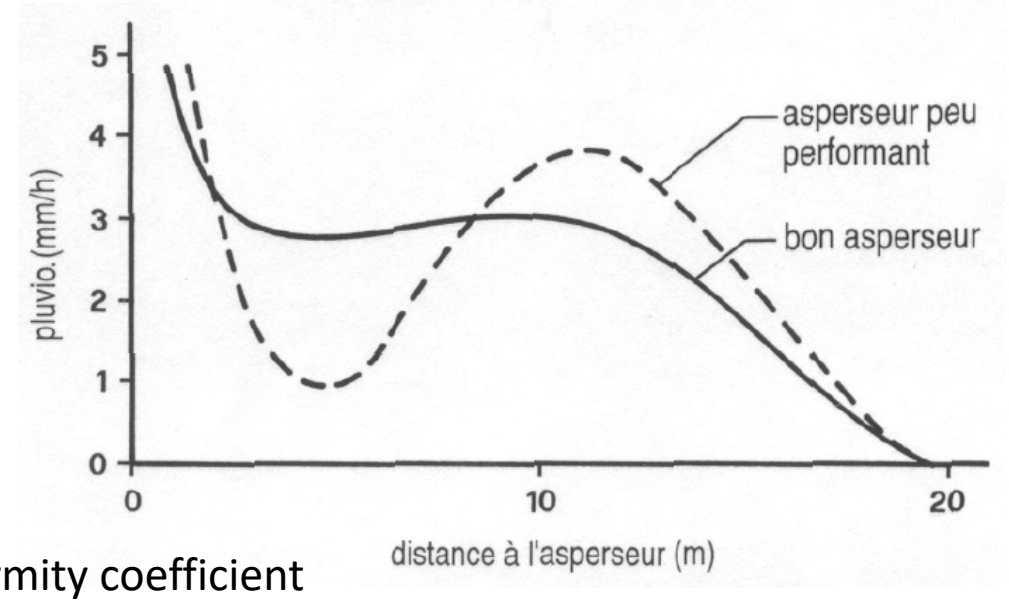
Spraying is not recommended when wind speeds constantly exceeds 20 km/h (ca. 7 m/s)

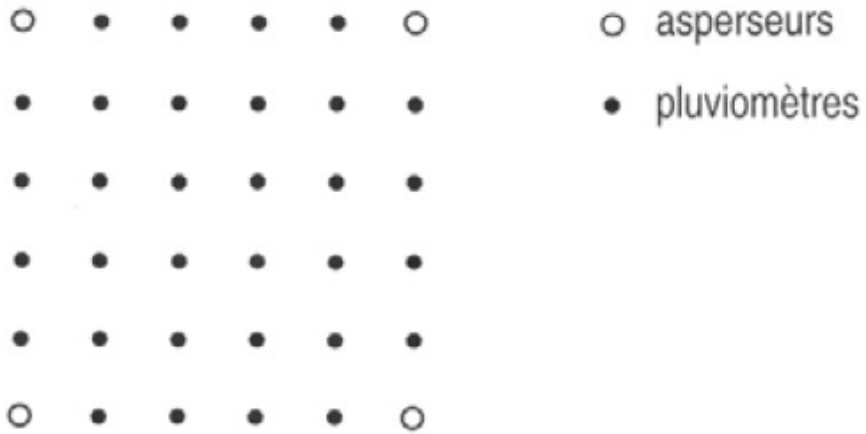
Spray uniformity measures

To determine spraying uniformity for:

- a given sprinkler
- a given nozzle
- a given pressure
- a given layout

can be characterised by a uniformity coefficient CU, e.g. the Christiansen uniformity coefficient :





Christiansen uniformity coefficient

$$CU = 100\left(1 - \frac{\sum|h_i - h_m|}{n h_m}\right)$$

h_i: rainfall recorded at rain gauge i

h_m: average rainfall

n: number of rain gauges

CU = 100 perfect uniformity

CU > 80 satisfactory uniformity

CU < 70 unsatisfactory uniformity

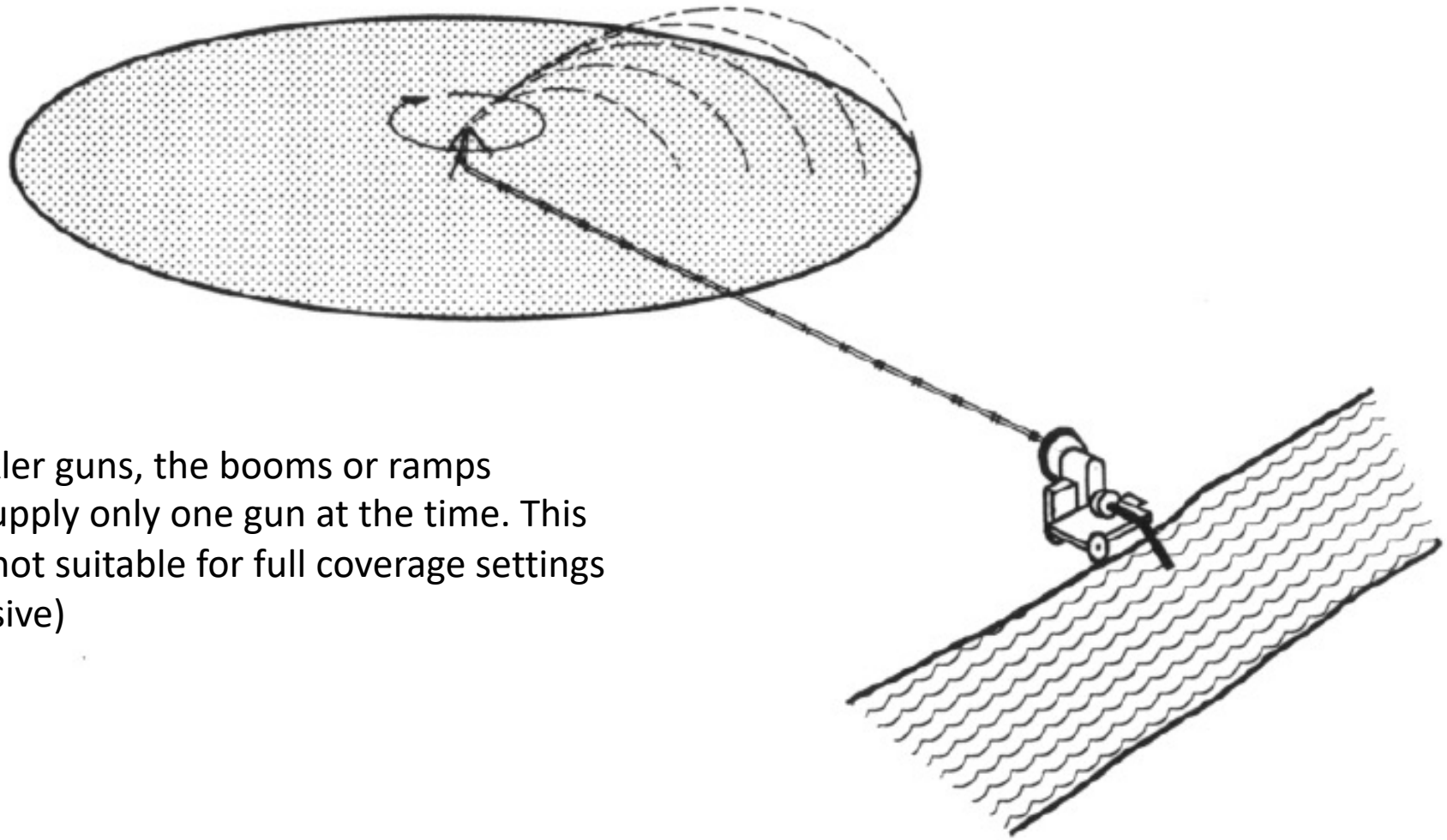
Practical organisation of irrigation

- Fully mobile installation
- Totally fixed installation
- Intermediate solutions

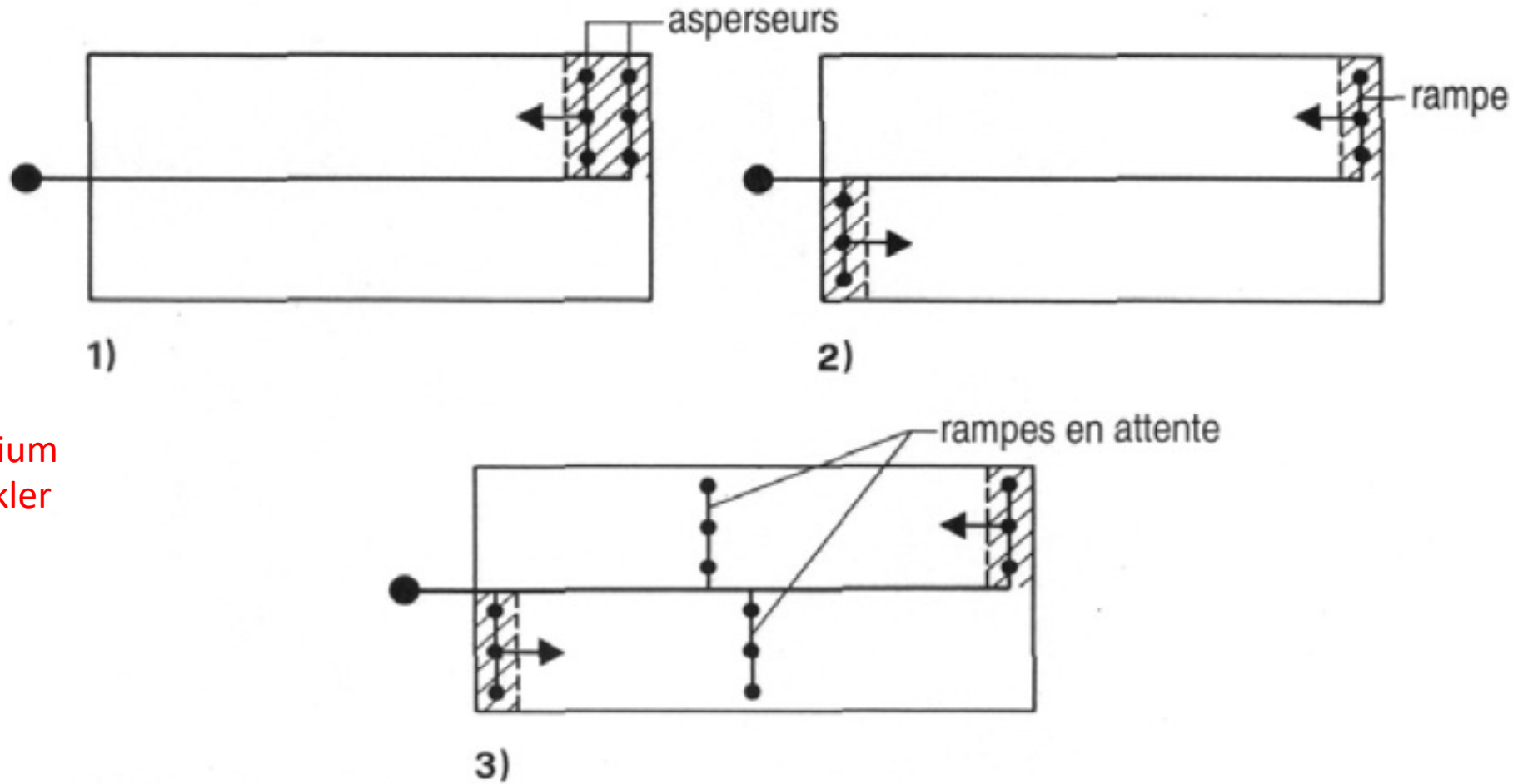
Station: area covered by all sprinklers operating simultaneously

Irrigation of the entire perimeter is carried out in several successive stations

Example of a mobile installation with a sprinkler gun



With sprinkler guns, the booms or ramps generally supply only one gun at the time. This solution is not suitable for full coverage settings (too expensive)

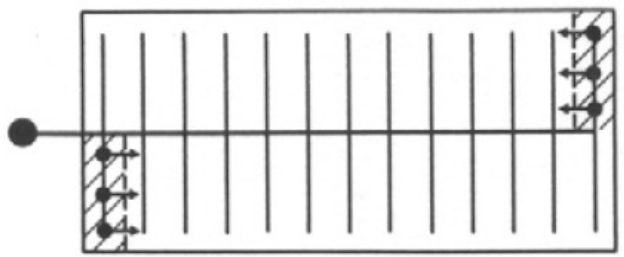


Typical of medium pressure sprinkler systems

Fig. 27 : Schéma de principe d'installations en couverture partielle

b) Couverture totale en canalisations et partielle en arroseurs

Toutes les canalisations sont fixes; seuls les asperseurs font l'objet d'une rotation.



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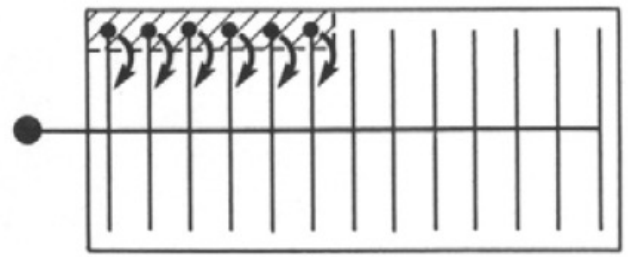
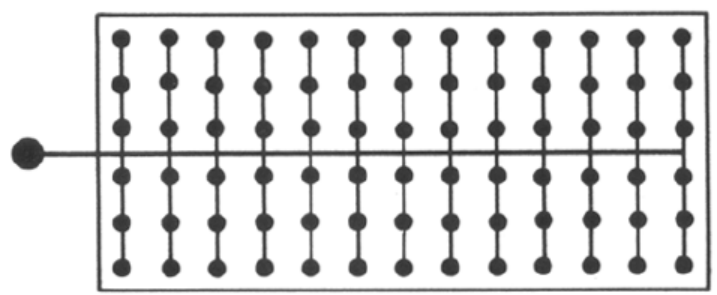


5)

c) Couverture intégrale

L'équipement d'irrigation (conduites, rampes et asperseurs) couvre l'ensemble du périmètre, si bien qu'il suffit de manoeuvrer des vannes pour passer d'un poste à l'autre.

Very costy, used mainly for fighting frost conditions (see ahead)



Fighting the frost with sprinkler irrigation

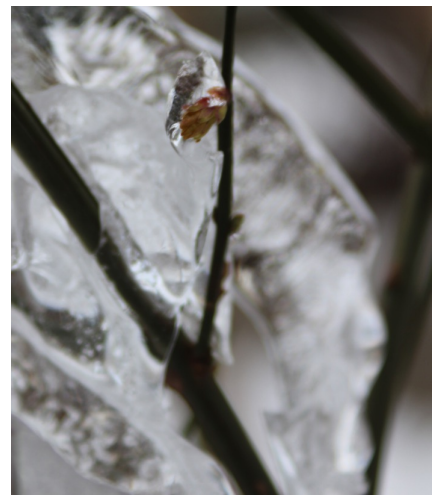
Frost types

- frost by radiation ($T_{vegetation} < T_{air}$)
- frost by advection: invasion by a cold air mass with a temperature < critical threshold ($T_{air} < T_{vegetation}$)
- frost by evaporation when plants are wet, air humidity is low and air temperature is close to the critical threshold (2500 kJ/g specific evaporation energy)

In Switzerland, the crops most at risk are fruit trees (peach, apricot, cherry, pear and apple) and vines (damage would cause high financial losses).

Factors affecting plants resistance to frost

- phenological stage
- species and variety considered
- changes in climatic conditions



Espèces	Stades phénologiques		
	Avant la floraison	Floraison	Après la floraison
Abricotier	- 4	- 2	0 à - 0.5
Poirier	- 4.5	- 3	- 1
Pêcher	- 4	- 3.5	- 1
Cerisier	- 4	- 4	- 1
Pommier	- 4.5	- 3	- 2

Critical temperatures for some fruit crops

Ways of fighting the frost

- plant cover
- protective smoke screens
- mixing the atmosphere
- heating the atmosphere
- spraying (→ - 7 °C)

costly, difficult to implement, limited effectiveness (gain 2 to 3 ° C at best)

Heaters

Antifrost tower

Remember the movie “A walk in the clouds”

https://www.youtube.com/watch?v=sYk8M_ZTNlY

Use of sprinklers

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Background:

While freezing water releases around 335 kJ/g along all directions

Purpose :

Provide sufficient, evenly distributed rainfall throughout the necessary period

Questions :

- What rainfall should be applied?
- How to ensure evenly distributed rainfall?
- When to start watering?
- When to stop spraying?

Homogeneity of the application

- choosing the right sprinkler
- sensible choice of nozzle*
- sensible choice of layout
- strict compliance with Christiansen's uniformity rule

* **4 mm < diameter < 5 mm**

Pluviometry of the sprinklers

Function of:

- type of crop to be protected
- air temperature and humidity

Values usually used :

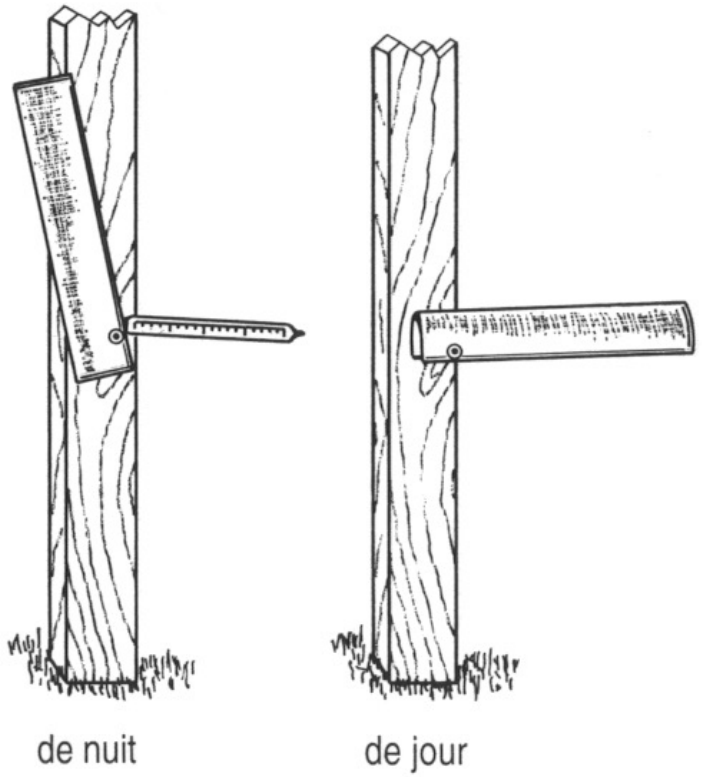
- low crops: 2 to 2.5 mm/h
- high crops: 3 to 4 mm/h

(sprinklers positioned approx. 0.5 m above crops)

Water consumption is therefore very high (between 15 and 40 m^3 per hour and per hectare).

Start of frost control

Relative air humidity > 80%.

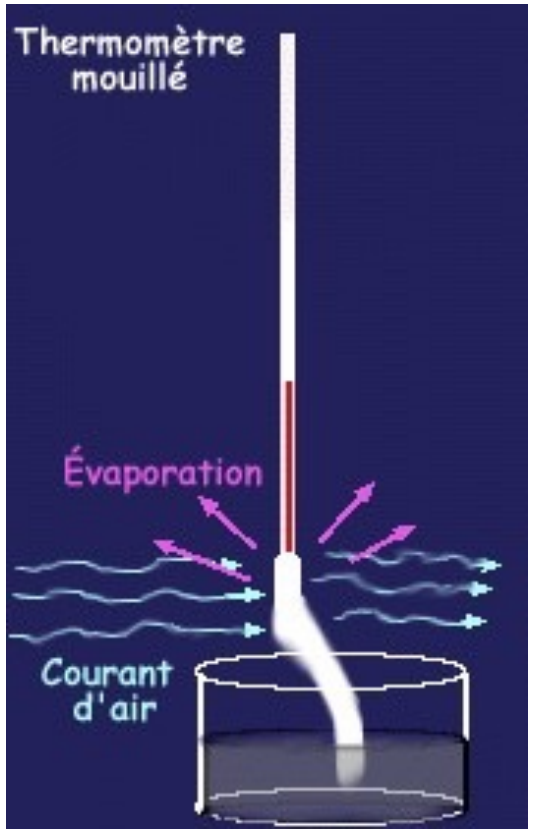


Use of data from an actinothermal index thermometer (alcohol thermometer, unsheltered) whose radiation properties are similar to those of plants.

Activation when the temperature indicated by the actinothermal index thermometer reaches 0.5 to 1 °C above the critical threshold.

Start of frost control

Relative humidity < 80%: risk of frost due to evaporation



Use of data from a wet thermometer* which indicates the temperature that the plants could reach when the sprinkler is switched on.

Activation when the wet bulb thermometer reads 0.5 to 1 °C

*** A thermometer whose tip is covered with wet muslin which is blown to evaporate the water.**

Stop frost control

Theoretical :

When the ice has completely melted

In practice :

- **air temperature > 2 °C**
- **when water appears under the ice**