Irrigation systems for organic greenhouse production (incl. use of root zone sensors)

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BioGreenhouse

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Background information

Improving irrigation water use efficiency is decisive to satisfy the increased world demand for food and other agricultural products.

- **Irrigation method**
- **Irrigation schedule** (**how often or when** water is given, and **how much** irrigation water has to be given to the crop)

is the key issue for

- conserving water,
- improving irrigation performance
- sustainability of irrigated agriculture.

Various types of irrigation methods and their systems are used in crop production in greenhouses and nurseries.

- Surface systems that apply water to the soil/substrate surface
  - Hand watering
  - Drip irrigation system
  - Microspray
- Overhead systems that apply irrigation water 'over the top' of the foliage
  - Sprinkler system
  - Mist and fog system
  - Boom system
- Subsurface systems (which apply water to the base of the root zone and rely on capillary action or flooding to bring water into the root zone)
  - Subsurface drip
  - Troughs
  - Flooded Trays
  - Flooded Floors

Irrigation Delivery Systems

- Pumps and pressure tanks may be used to increase or stabilize the hydraulic pressure
- Injectors are used to inject various nutrients into the water. Mixing or blending tanks assure that the dissolved materials are distributed uniformly within the water
- Filters are placed to remove insoluble materials.
- All irrigation systems consist of tubing and/or pipe to transport the irrigation water from the source to the individual plants or to a group of plants

- **Minimizing the pressure drop within the system, and especially the variation in pressure among the emitters, maximizes irrigation uniformity.** It is important to design of irrigation systems properly so that all of the parts (main lines, valves, pressure regulators, laterals and emitters) are correctly sized to deliver water at the desired pressure and flow rate.
- **Well-designed and well-maintained irrigation system having with high uniformity (q var ≤ 10 %) should be kept**.

Drip irrigation

- Drip irrigation is the slow localized application of water, at a point or grid of points on or just below, the soil surfaces.
- Water is supplied to the plants by set of plastic tubes laid on the ground or buried at a depth of 15-40 cm
- Drip laterals are left in place throughout the irrigation season.
- Laterals are 12-20 mm in diameter and either perforated or fitted with a special emitters.
- The discharge in the range of 1-8 liters/hr per emitter, should not exceed the soils infiltrability

Drip irrigation

Advantages

- Significant saving of water, nutrients and operating cost are possible (if this is designed and managed correctly).
- Water use efficiency can be higher under drip irrigation because of less evaporation, continously high soil water at near the field capacity and lower root zone salinity
- Reduced weed problems and non-wetted soil surface resulting in easy operation.
- Water distribution is highly uniform (efficiency of water application ≥ 85%), if maintenance and construction is done properly.
- Fertigation can easily be included with minimal waste of fertilizers.
- The plant and fruits remain dry, reducing the risk of disease.
- Easy to automate the system

Disadvantages

- Clogging is a serious risk if the water is not properly filtered and the equipment not properly maintained.
- Susceptibility to clogging of drippers may lead to the more expensive system depending on water quality.
- Drip tubes cause extra labour after harvest and before planting.
- Salts tends to accumulate at the soil surface and around the wetted area.

Drip irrigation systems

- Storage reservoir and/or water source,
- Control unit
  - pumps,
  - non-return valve
  - dilution equipments,
  - Filters (sand separator, sand filter, screen filter disc filter etc),
  - pressure regulators,
  - water meters,
  - Valves (Solenoid valves should be used if irrigation control is to be automated).
- mainline,
- submain lines
- laterals and
- emitters.

- A drainage system is also required to collect the drainage solution.
- In closed system, a reservoir and disinfection equipment e.g. UV, heat system or slow sand filters should be installed for recycling and disinfection.

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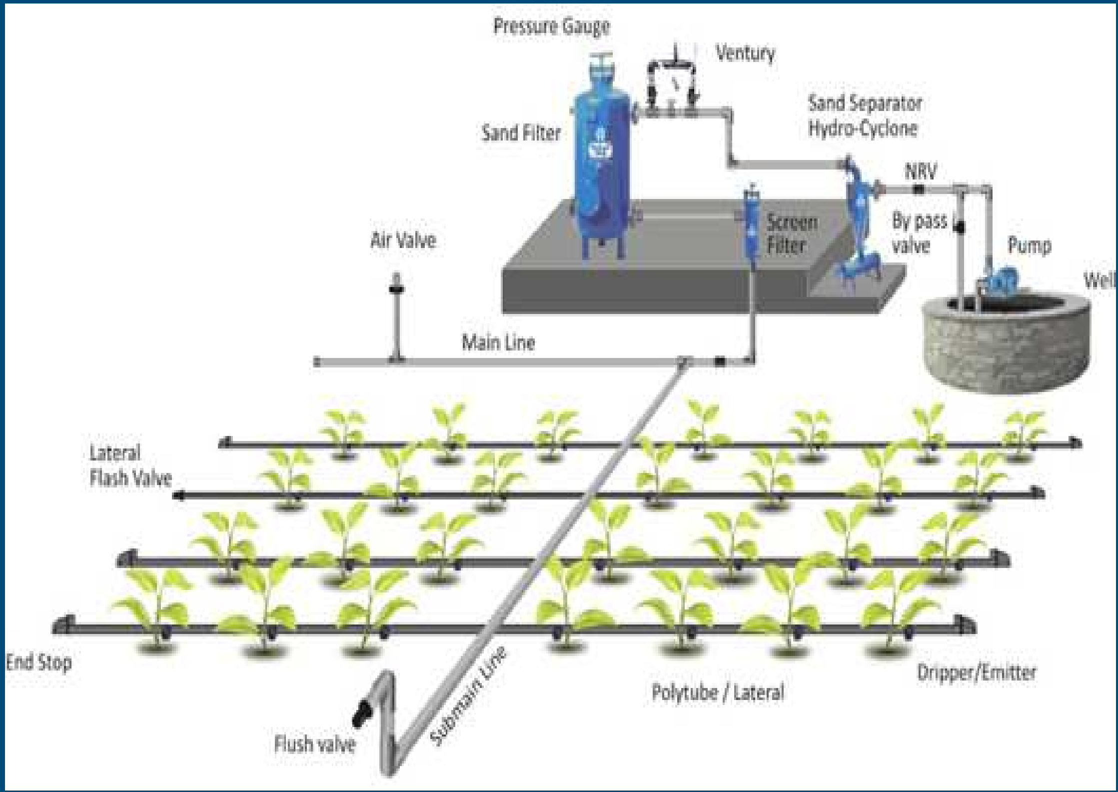
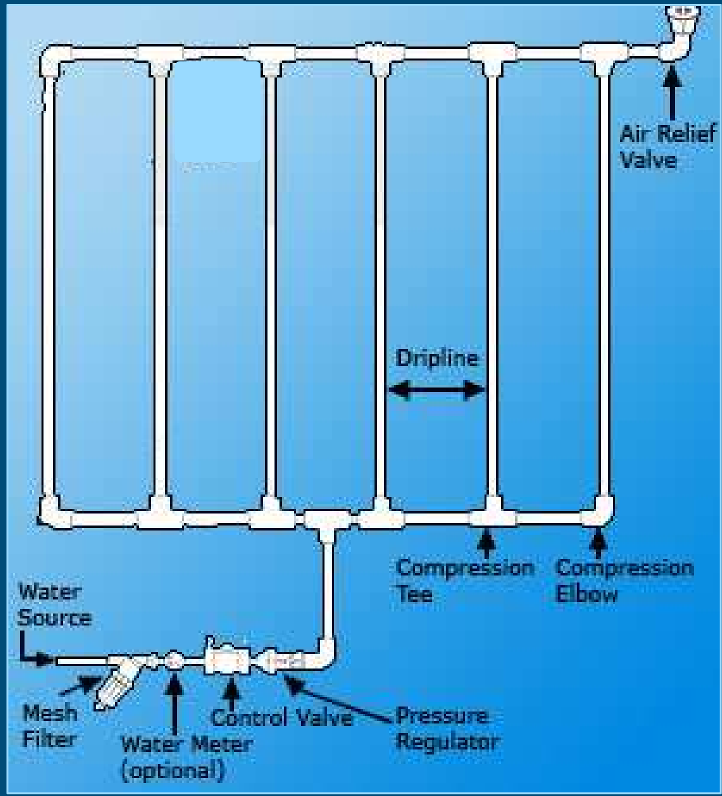


Drip Irrigation



Subsurface Drip Irrigation

- Various emitters are also available in a wide range and should be selected according to the type of growing techniques.
  - punch-in emitters and built-in emitters
  - emitters having flushing feature
  - pressure compansating emitters
  - non-drip emitters
  - emitters have multiple outlets









Sprinkler systems

Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall, hence the whole surface is irrigated. The spray lines are placed high in the greenhouse, above the crop canopy. The plants are wetted with each irrigation event.

Advantages

- The whole surface and root zone is wetted,
- Fertigation can be included, but proper programming during the irrigation event is necessary to avoid nutrient precipitation on the leaf canopy.

Disadvantages

- The plants become wet each time.
- The irrigation intensity is relatively high; short irrigation rounds are technically difficult and lead to high heterogeneities, hence leaching is a risk.

- Irrigation with sprinklers allows large cropped areas in either glasshouse or polytunnels.

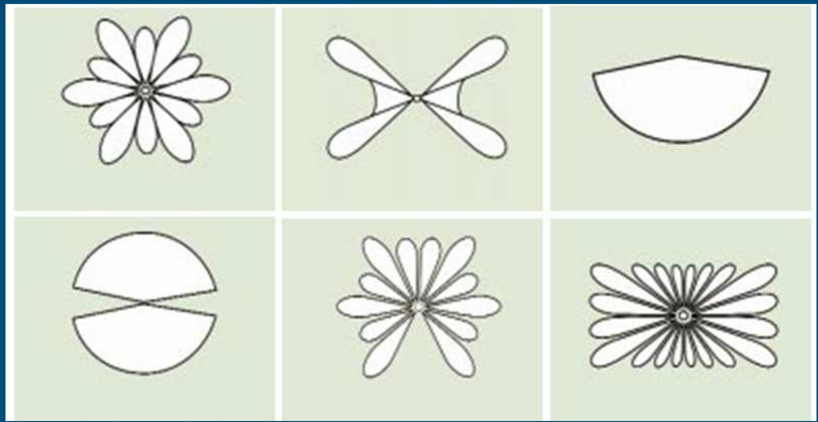
- Anti-drip nozzle which hold the water in the lines should be used to avoid any dripping onto the crop after switched off the system.

- Fogging/humidification nozzle can also be used instead of sprinkler to irrigate different crops. This is the ideal solution for cooling and humidifying of the glasshouse or the Polytunnel,

- A boom system consists of one or more pipes containing nozzles that apply water as the system moves over the plants.
- It may be suspended from an overhead rail system. Water is supplied by a trailing hose and powered by a battery pack or electric supply cable.
- Each boom system is independently designed to the growers needs

Strip irrigation by mini sprinklers and sprayers

Irrigation water is applied only as small strips or only as one plant row. The system is placed just at the soil surface keeping the crop dry during irrigation



Wetting patterns

Subirrigation systems

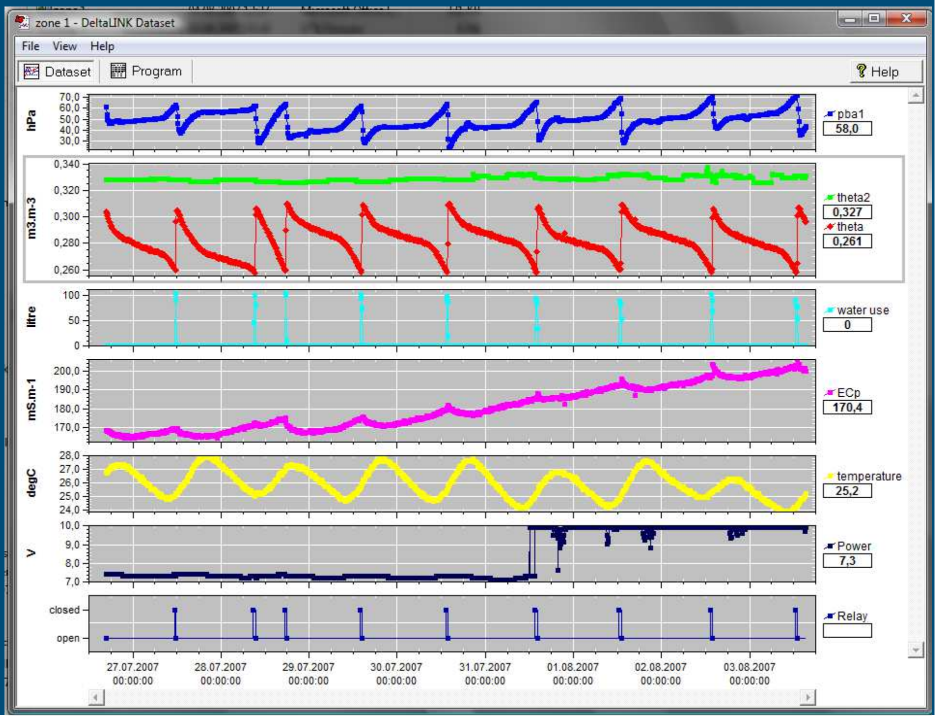
- These systems deliver water and nutrients at the base of containers and the dampening of soil/substrates arises from capillarity
- They are closed systems that recirculate water from a central reservoir to benches (e.g. ebb-and-flow, trough) and flooded floor systems, and the solution is drained back to the reservoir after irrigation.
- Collection trays and capillary mats are also efficient subirrigation systems.

irrigation scheduling methods can be based on;

- **soil monitoring**
- **plant monitoring**
- **soil-water balance**
- **simulation**

potential benefits of soil moisture sensors

- ❑ Provide feedback on soil moisture level for correct scheduling of irrigation
- ❑ Provide additional information on soil environment eg. soil temperature, electrical conductivity (EC).
- ❑ Determine effectiveness of irrigation - monitor wastage through deep drainage
- ❑ Evaluate/analyse plant demand for water
- ❑ Detect leaching of nutrient.
- ❑ Switching of irrigation controller
- ❑ Save water by improving irrigation effectiveness
- ❑ Reduce water wastage



sensing techniques

- ***volumetric***

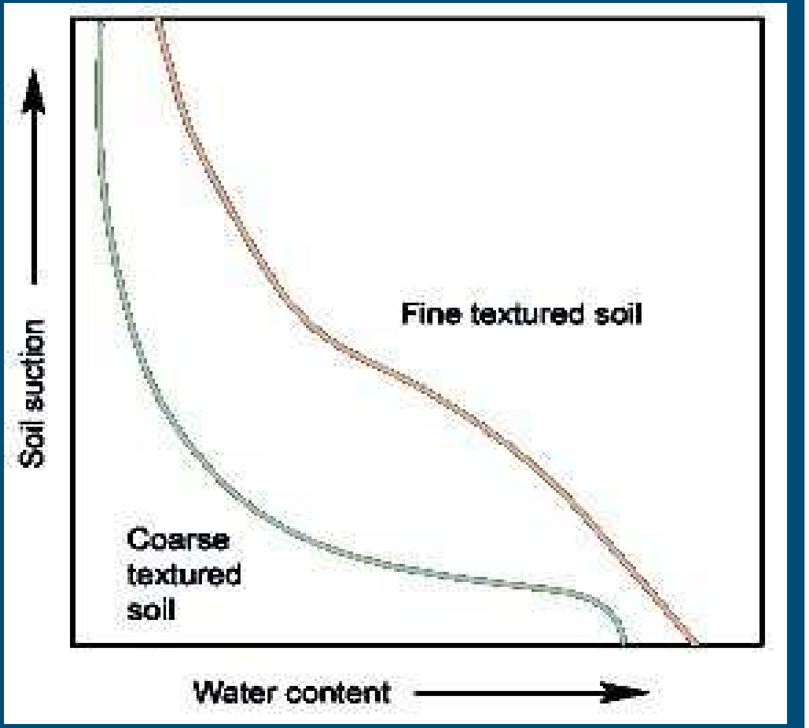
(Water content sensors (VWC) measure the total water held in the soil i.e. water locked into the soil structure plus available water)

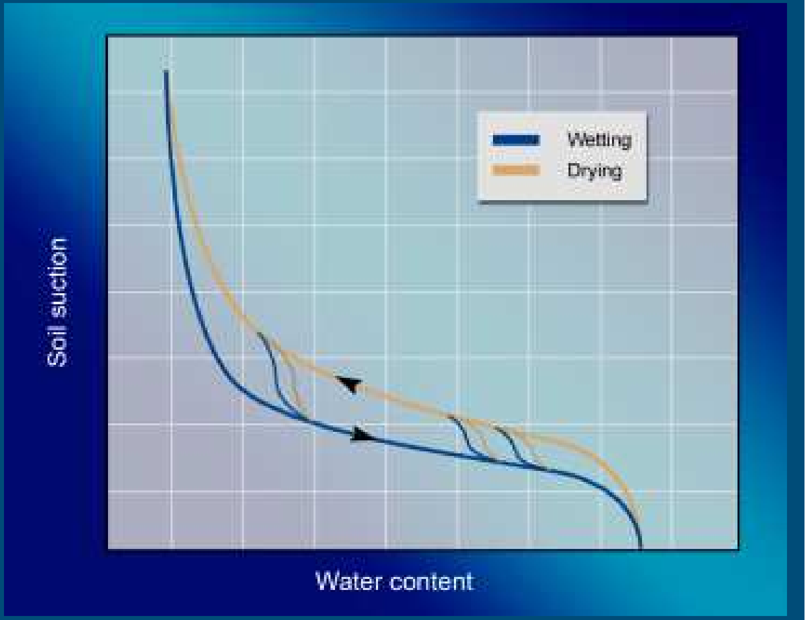
and

- ***tensiometric***

(Matric potential sensors measure the effort required to extract the water from the soil)

- Both quantities are related through the soil water characteristic curve
- Each soil type (texture/structure) has a different curve.
- Relationship might not be unique and may differ along drying and wetting cycles, especially in finer soils.





Volumetric Methods

- All volumetric water content sensors estimate the volume of water in a sample volume of undisturbed soil

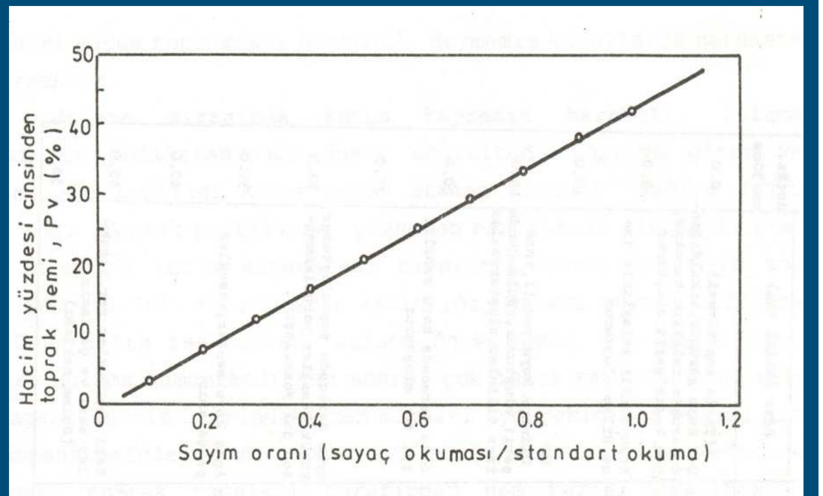
- This quantity is useful for determining how saturated the soil is (i.e. fraction of total soil volume filled with the soil aqueous solution).

- When it is expressed in terms of depth (i.e. volume of water in soil down to a given depth over a unit surface area (mm of water), it can be compared with other hydrological variables like *precipitation, evaporation, transpiration, deep drainage*, etc.

Neutron Moderation

- Fast neutrons are emitted from a radioactive source ($^{241}Am/^{9}Be$) and when they collide with particles having the same mass as a neutron (i.e., protons, H^{+}), they slow down dramatically, building a “cloud” of “thermalized” (slowed-down) neutrons.

- Since water is the main source of hydrogen in most soils, the density of slowed-down neutrons formed around the probe is nearly proportional to the volume fraction of water present in the soil.



DIELECTRIC METHODS

- Soil water content is estimated by measuring the soil bulk permittivity (or dielectric constant), Ka_b, that determines the velocity of an electromagnetic wave or pulse through the soil.
- In a composite material like the soil (i.e. made up of different components like minerals, air and water), the value of the permittivity is made up by the relative contribution of each of the components.
- The total permittivity of the soil or bulk permittivity is mainly governed by the presence of liquid water since the dielectric constant of liquid water ($Ka_w = 81$) is much larger than that of the other soil constituents (e.g. Ka_s = 2–5 for soil minerals and 1 for air),
- **These techniques are becoming widely adopted because they have good response time (almost instantaneous measurements), do not require maintenance, and can provide continuous readings through automation.**

There are different types of dielectric sensors depending on the output signal used for estimating VWC

- Time Domain Reflectometry (TDR),
- Frequency Domain (FD) (Reflectometry and Capacitance),
- Time Domain Transmission (TDT),
- Amplitude Domain Reflectometry (ADR)
- Phase Transmission sensors.

All these sensors differ in terms of

- electronics
- use and maintenance,
- calibration requirements, accuracy and
- price.

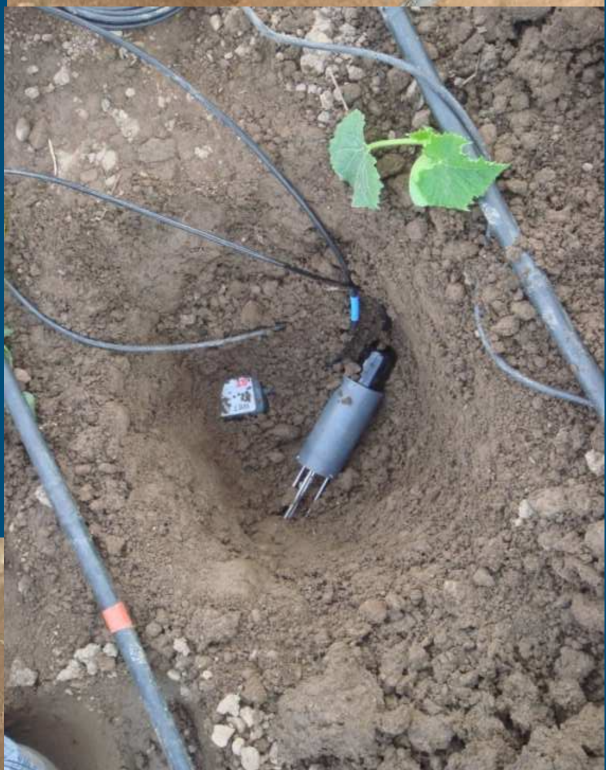
TDR uses a pulsed excitation wave while FD uses a fixed frequency sine wave to measure the soil impedance. The precision and the accuracy of TDR and FD sensors depend on the wave form interpretation methods used in software .

Most of sensors are based on the relationship between VWC and dielectric constant (permittivity) of soil according to the Topp's equation.

$$\mathbf{VWC = -5{,}3x10^{-2} + 2{,}29x10^{-2}Ka_b - 5{,}5x10^{-4}Ka_b^{2} + 4{,}3x10^{-6}Ka_b^{3}}$$

(The relationship depends on the electromagnetic wave frequency sent by the specific device. At ***low frequencies (<100 MHz) it is more soil-specific).***

The permittivity can be valid for the soils with low clay content and a bulk density between 1.3 and 1.5 kg L^{-1}. For other kinds of soil special calibration is generally required .



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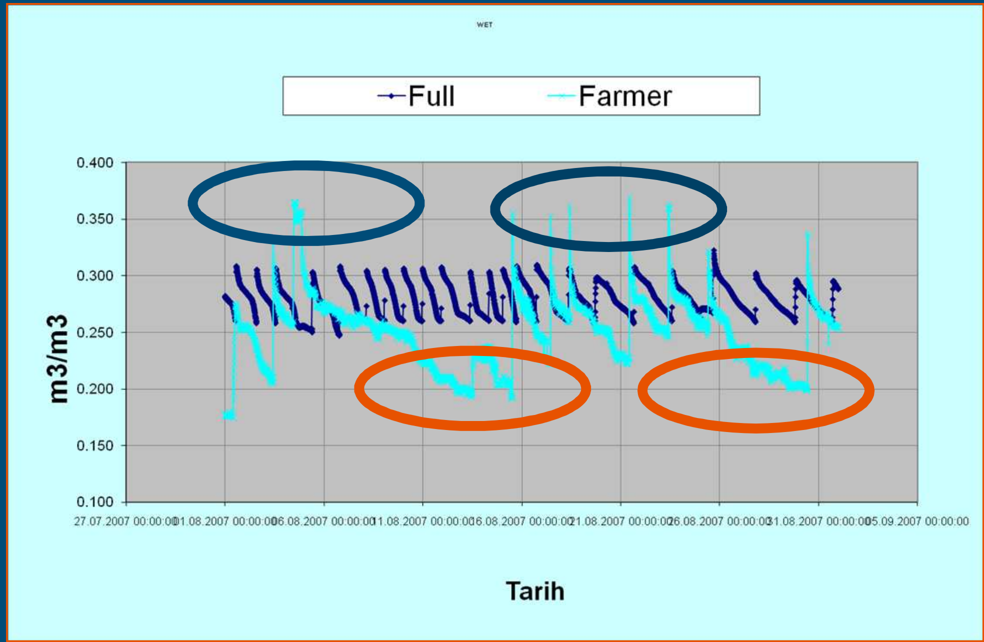
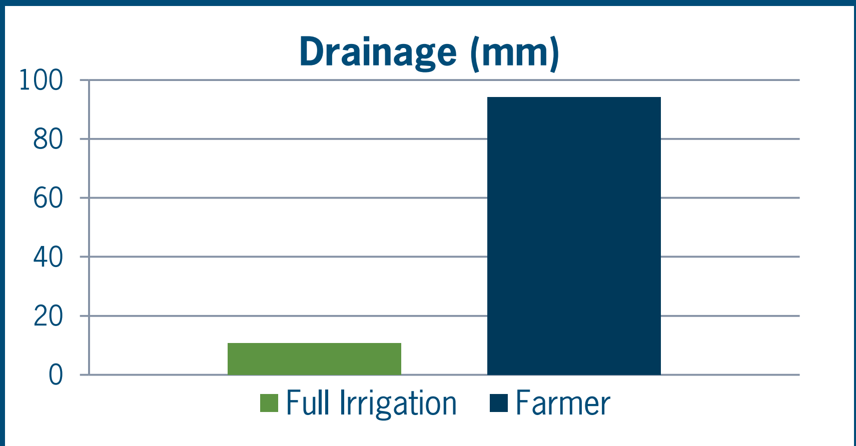
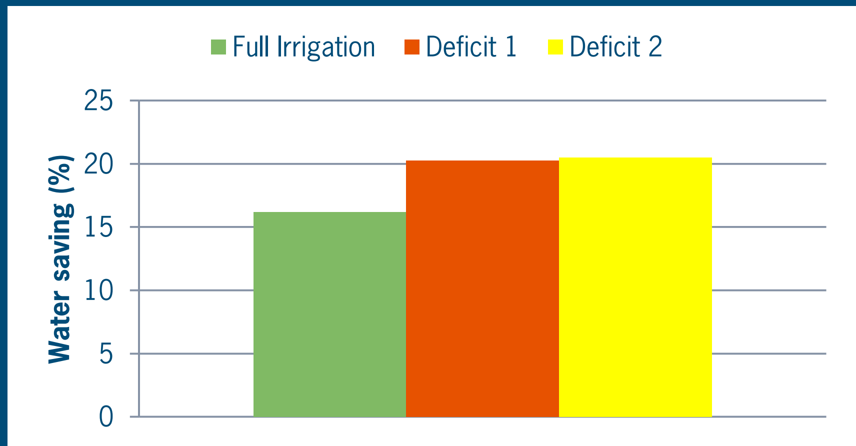


Full
Farmer
0.400
0.350
0.300
0.250
0.200
0.150
0.100
m3/m3
Tarih

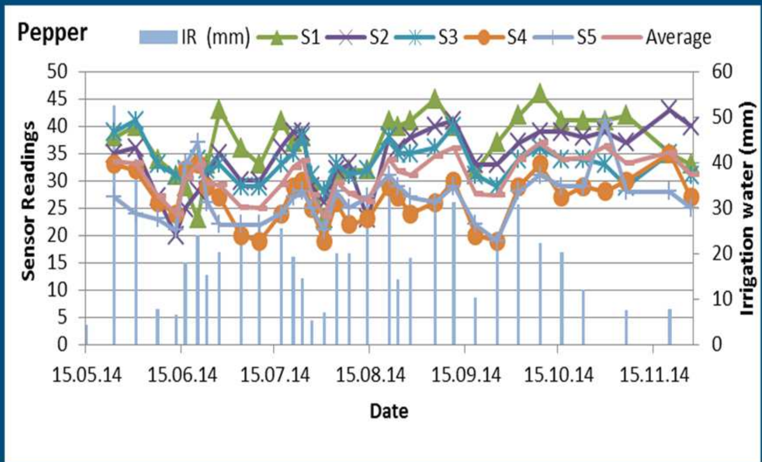


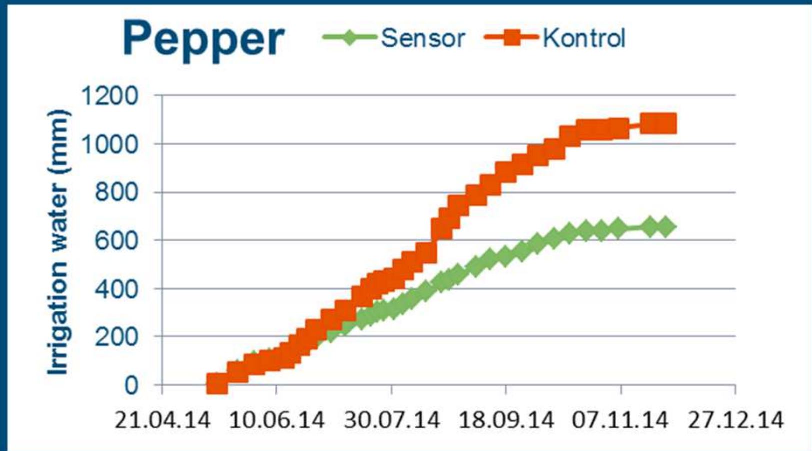
Drainage (mm)
100
80
60
40
20
0
Full Irrigation
Farmer



Full Irrigation
Deficit 1
Deficit 2
25
20
15
10
5
0
Water saving (%)

Aquatag/Sutek





Treatment	Irrigation water(mm)	Yield(kg/m2)	WUE (kg/m3)
Sensor	655	5,23	7,98
Control (Farmer)	1083	4,64	4,28

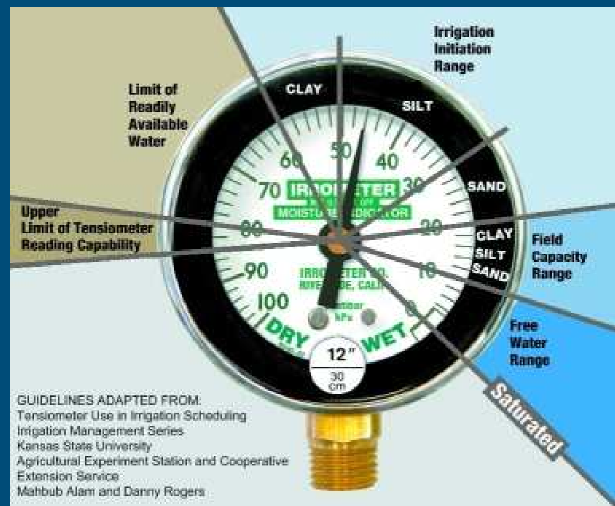
Soil water potential methods

- Tensiometer
- Porous matrix sensor
- Resistance Blocks and Granular Matrix Sensors
- Soil Psychrometer
- Heat Dissipation

Tensiometer

- A tensiometer is a kind of artificial root that measures (ψ_m) in the soils. The tensiometer consists of a shaft filled with water with a porous ceramic cup at the end and a dial vacuum gauge at the top.

- The shaft is generally made of plastic due its low heat conduction and high resistance to corrosion. The ceramic cup has small air entry potentials in order to prevent de-saturation when subjected to negative potentials.



- The pressure transducer can be connected to a data-logger for long-term monitoring
- Hand-held meter for spot measurements or to an irrigation controller.
- Limited soil suction range (<1 bar)

Resistance Blocks and Granular Matrix Sensors (GMS)

- The electrical resistance between electrodes embedded in a porous medium (block) is proportional to its water content, which is related to the soil water matric potential of the surrounding soil.
- Measurement range is 0.3–2.0 bar .

Porous matrix sensor

- The porous-matrix sensor follows another approach to the measurement of ψ_m .

- Soil ψ_m is determined indirectly from the measurements of the water content of the ceramic, for instance by means of dielectric sensor.

- Such sensors are commercially-available (e.g., equitensiometer; Delta-T Devices Ltd.). They can work in frozen and dry soils with ψ_m as low as –500 kPa. Moreover, they do not need maintenance for refilling or degassing likewise water-filled tensiometer.

- Recently, Whalley and colleagues have designed a new dielectric tensiometer that works over a much wider range of ψ_m.
- A number of prototypes of this sensor have been tested both in the lab and in a greenhouse cucumber crop in Turkey.
- Good results have been achieved with these sensor prototypes that are able to measure soil ψ_m over the nominal range from –3 kPa to –250 kPa.
- These sensors might be commercially available in near future.

Conclusion

- Improving irrigation efficiency is related to the selection of irrigation method and irrigation schedule based on the plant growing conditions.
- Soil moisture sensor technology has promised a lot over the past decade and the technology is continuing to be developed and refined.
- Expensive and sophisticated root zone sensors (RZS), such as neutron probes, TDR, FDR are available for the use of soil and plant scientists, while cheap and practical devices are needed for irrigation management in commercial crops.
- Future research should focus on developing new techniques or improving the available actual methods to overcome the main limitation of requiring a soil-specific calibration.
- Further refinement of non-contact and remote sensing techniques shows promise to evaluate soil moisture distribution and variation across large scales

Thank you for your attention

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