Deliverable 2.3

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[Farmers practical guides]

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Summary

In this deliverable, a practical user guide for farmers is developed to describe the technical aspects to be considered in choosing the most suitable location for sensor installation and maintenance. These practical user guides cover both greenhouse and open-field crops grown in the Mediterranean area regarding the best fertigation protocols for each of the PRECIMED regions, namely Spain, Greece, Algeria, and Tunisia. The main objectives of this deliverable under Work Package 2 (WP2) are to boost and promote precision agriculture among farmers and to provide information on irrigation and fertilization protocols based on specific areas and cropping practices. Furthermore, this work aims to inform about risk management and prevention actions to ensure sustainability by addressing appropriate and user-friendly methodologies based on the main elements used in the PRECIMED Decision Support System (DSS). Finally, an end-user friendly way to estimate crop nutrient requirements and crop irrigation dose and frequency is presented.

1. Presentation of the DSS for open-field and greenhouse crops

The use of new technologies in the agricultural sector, such as the Internet of Things (IoT), is more and more promoted and adopted by farmers, as it has confirmed how these technologies could lead to improve farm management. In this sense, the PRECIMED DSS is a decision support system aiming to optimize fertigation management and consequently improve water and nutrient use efficiency. PRECIMED DSS provides customized recommendations for irrigation management specific to individual crops, sites, and conditions. PRECIMED DSS has been validated for specific crops, cultivation systems, and environmental (climate and soil) conditions. In this sense, under the frame of the PRECIMED project, two different DSS approaches have been validated; the DSS for (a) open-field crops and (b) greenhouse crops.

1.1. DSS for open-field crops

The DSS for open-field crops is hosted in the PRECIMED platform. This platform is a webpage service where according to the sensors deployed at farm level, the user can monitor and manage different aspects of the farm from anywhere. The DSS has been developed to optimize the irrigation management with the help of soil moisture sensors and climatic data. Soil moisture sensors can contribute significantly to crop water and nutrient management by ensuring not only that the crops have an adequate water status but also limiting the drainage to ensure a minimal nutrient leaching. Evapotranspiration data can also be used to calculate a general water budget for a crop. This data is used to schedule irrigation events by replacing the water lost from the plant soil system by a process of soil moisture accounting. Irrigation events are scheduled when the soil moisture reaches the low limit point of the Readily Available Water (RAW) calculated for the soil.

As a result, the DSS provides irrigation recommendations, which can be used to adjust easily each irrigation event to specific crop requirements and soil characteristics, aiming to improve yields and fruit quality.

The DSS has an integrated irrigation protocol which is based on the information recorded by the soil probes installed at the farm. It is important, as it will be explained later, that the soil probes are deployed in a representative location of the farm, and that independently to the type of sensors, they register different depths of the soil profile by means of one or several soil moisture sensors. These sensors will register the volumetric soil water content (θv) every 15 minutes at the PRECIMED platform and the measurements are used as a control system variable.

In order to schedule irrigation, the DSS is focused in two specific depths (40 and 60 cm, level 4 and 6, respectively), based on the evidence that for drip irrigated woody crops, the more active roots are located in the first 50 cm of the soil profile (Intrigliolo et al. 2012). The information obtained from the soil probes was used to guarantee that soil water content was maintained in an optimum range between these two levels, avoiding the drainage at level 6 and ensuring appropriate and constant soil moisture at level 4 with every daily irrigation event. Therefore, the dynamics of the soil moisture on these levels after irrigation were monitored and according to their results, irrigation was programmed based on the following rules:

In level 4 (40cm depth):

- A40 – B40 > 1* indicates that water reached level 4, so irrigation is maintained.
- A40 – B40 < 1 indicates that water did not reach this level, so irrigation time is increased by 15% for the next day.

Where A40 stands for the absolute value of the moisture level at 40cm one hour after the first irrigation event of the day ends and B40 is the value of the moisture level when the first irrigation event of the day starts.

In level 6 (60cm depth):

- A60 – B60 ≥ 0.3* indicates that water reached level 6, so irrigation is reduced for the next day by 15%.
- A60 – B60 < 0 indicates that water did not reach level 6, so there is no water drainage of the more active root zone.

Where A60 stands for the absolute value of the moisture level at 60cm two hours after the first irrigation event of the day ends and B60 is the value of the moisture level when the first irrigation event of the day starts.

* Several tests have been done to establish the minimum variations that the results have to report to increase or decrease the irrigation timing. Thereby, a 15% of the settled time was considered as an appropriate value to both actions, which lied on the increase the irrigation time when water did not reach level 4 or decrease it when water reaches level 6.

There are some premises that the protocol followed:

- Season starts with one hour of irrigation per day.
- Irrigation events have to be larger than 60 minutes and shorter than 240 minutes.
- When the timing exceeds 240 minutes, irrigation is divided into two events per day.
- Calculations are done two hours after irrigation ends.

There is a user interface in the PRECIMED platform to configure and run the CEBAS DSS model, showing the returned recommendations made by the model for the end-user for the plot.

The DSS module will retrieve historical data from the IoT platform for the electrovalve linked with the irrigation system to find the last irrigation period (between the last on/off interval). With this information the DSS module retrieves the historical data of the two soil moisture sensors to estimate the needed recommendations for the next irrigation.

1.1.1. DSS Management guide

To access to the platform, a previous registration is requested. After registration, the user must log in any time to enter at the PRECIMED platform and once this step is done, a "Home" panel will show the different controllers that the service offers.

Clicking in "Parcels", it will take us to the list of the previously entered parcels with their specific characteristics. To access to the DSS, click on the plot to control and then in the upper horizontal menu click on "DSS" (Figure 1).

Figure 1. Platform screenshots for access to PRECIMED DSS

To obtain the irrigation requirements of the farm, the inputs that are used to run the DSS must be configured (Figure 2). In this example the soil moisture sensor used is a Drill and Drop probe which registers θv at six different depths, i.e., from 10 to 60 cm below the surface. Following the example, the inputs are:

- **Root Sensor Id**. To select the ID of the soil moisture sensor deployed in that area with a mayor root activity.
  - ***Roots ground level***. This number is used to identify the depth of the sensor which will be monitored, where 1 is the upper level (10cm depth) and 6 the deepest one. A value >0 is used when the sensor is integrated in a multilevel probe (as the example), however if it is a standalone sensor, it takes the value of 0.

  - ***Roots threshold***. Stands to indicate the desire threshold value of the soil moisture before and after irrigation, to decide if the next irrigation event should be incremented or not.
  - **Roots *time-lapse***. Indicates the time, in hours, in which the system will check if the soil moisture is higher or not in the selected level.

- **Drain Sensor Id.** To select the ID of the soil moisture sensor deployed at drain level.
  - ***Drain Ground Level***. This number is used to identify the depth of the sensor which will be monitored, where 1 is the upper level and 6 the deepest one (60 cm). A value >0 is used when the sensor is integrated in a multilevel probe. If it is a standalone sensor, it takes the value of 0.
  - ***Drain threshold.*** Stands to indicate the desire threshold value of the soil moisture before and after irrigation, to decide if the next irrigation event should be reduced or not.
  - ***Drain time-lapse***. Indicates the time, in hours, in which the system will check if the soil moisture is higher or not in the selected level.

- **Water valve controller Id.** The ID of the electro valve deployed to control irrigation.
  - ***Base irrigation.*** Irrigation time (minutes) to be applied, just during the first configuration or in case of any adjustment of the settings.
  - ***Minimum irrigation time***. The minimum irrigation time (minutes) applied to the crop.
  - ***Maximum irrigation time***. The maximum irrigation time (minutes) applied to the crop.
  - ***Percentage increment.*** The time percentage (%) in which irrigation will be increased or reduced when needed according to the previous rules. As it is mentioned above, a 15% can be a good value.

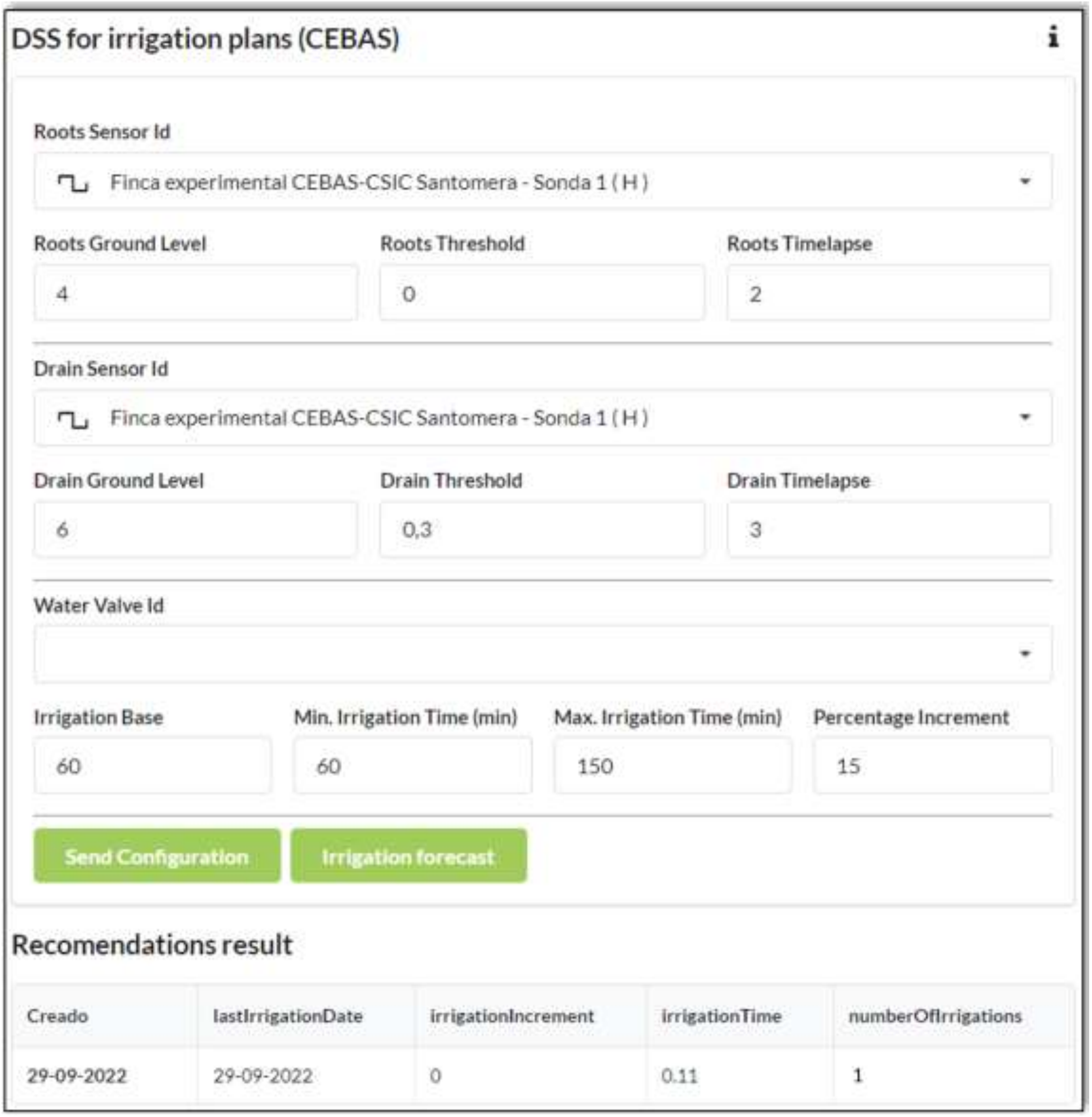


Figure 2. Frontend of the DSS for open field crops

Finally, by clicking on "Irrigation forecast" the DSS model returns the recommendations for the next irrigation event using the next parameters:

- Irrigation increment. The percentage (%) of the estimated irrigation increment to be applied.
- Irrigation duration. The duration (minutes).
- Number of irrigations. The number of irrigations to be applied.

Besides these recommendations to set the irrigation, the platform offers the possibility to automate this process and program automatically the next irrigation event in base of the daily calculations.

1.2. DSS for greenhouse crops

The PRECIMED DSS was developed to improve water and nutrient use efficiency in a hydroponic greenhouse in the Mediterranean region, promoting precision agriculture for better resource management. The model takes into account several climatic inputs such as the daily maximum and minimum temperature and solar radiation and simulates crop dry matter production (DMP) and crop transpiration. Then, considering the optimal nutrients content in the dry matter and the nutrient absorption concentration, the optimal ion concentration in the fertigation nutrient solution that has to be supplied to the plants is estimated. The results of the implementation showed that the application of such a DSS could result in a significant reduction of macronutrient use without affecting productivity. The ultimate purpose of this DSS is to provide the end-users with a tool that will estimate on a weekly basis the optimal composition of the irrigation nutrient solution based on the growth stage of the crop and the weather conditions, as an alternative to the current practice where the composition of the nutrient solution changes about two to three times during the growth period. The application of the PRECIMED DSS could significantly contribute to the improvement of the current situation in the agricultural sector since its application will contribute to the reduction of the fertilizer use, helping both the environment and the end-user. An insight into the initial PRECIMED DSS written in an excel document is presented in Table 1.

Table 1. Inputs needed for the PRECIMED DSS and obtained outputs resulting in a weekly nutrient recipe recommendation.

	INPUTS					
	Daily maximum T [°C]	Daily minimum T [°C]	Daily avg of Solar radiation [W/m²]	Total irrigation volume [L/m²]	Total drainage volume [L/m²]	Crop transpiration [L/m²day]
DATE	T_{max}	T_{min}	Rs_i	Ir	Dr	ET_c
12/10/2021	34,46	15,60	230,58	0,8	0,5	0,34
13/10/2021	33,92	14,06	213,71	0,8	0,5	0,34
14/10/2021	19,05	15,13	25,20	0,8	0,5	0,34
15/10/2021	21,63	13,87	61,81	0,8	0,5	0,34
16/10/2021	28,49	14,29	136,43	0,8	0,5	0,34
17/10/2021	31,35	12,57	152,85	0,8	0,5	0,34
18/10/2021	37,01	14,23	164,93	0,8	0,5	0,34

OUTPUTS										
Dry matter production [t/ha]	Critical crop N uptake [mmol/m²]	Critical crop P uptake [mmol/m²]	Critical crop K uptake [mmol/m²]	Critical crop Ca uptake [mmol/m²]	Critical crop Mg uptake [mmol/m²]	Final Nutrient Concentrations				
DMP_i	N	P	K	Ca	Mg	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0,11	4,08	0,36	1,07	0,63	0,39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0,12	3,97	0,35	1,05	0,61	0,38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0,12	4,12	0,36	1,10	0,64	0,40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0,12	4,30	0,38	1,15	0,67	0,42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0,12	3,01	0,26	0,80	0,47	0,29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0,13	3,62	0,32	0,97	0,56	0,35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0,14	4,29	0,37	1,16	0,67	0,42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Weekly Precimed_Nutrient Suggestion				
N (mmol L⁻¹)	P (mmol L⁻¹)	K (mmol L⁻¹)	Ca (mmol L⁻¹)	Mg (mmol L⁻¹)
11,50	1,01	3,07	1,78	1,11

2. Guidelines for DSS/sensors installation

2.1. Guidelines for sensor installation in open field crops

Depending on the approach, irrigation scheduling might require different types of devices to obtain the information which will be processed in the platform or analyzed by the user. Some examples of these devices are listed below:

2.1.1. Daily climatic data. Installation of an Automatic Weather Station

Selecting an appropriate site for a weather station is critical to obtaining useful weather observations. For agricultural applications, the station should be located in a place that best represents field conditions. The installation site needs to be far from obstacles at about 10 times its height. The ground needs to be covered by a green crop during the entire year with a height at about 12 cm. Perfect siting is not always possible but, depending on the application and sensors installed, the following rules should be observed:

- **Wind speed and direction:** Wind sensors should be located over open, level terrain as far away from any nearby obstructions (e.g., trees, greenhouses) as possible—ideally a distance equal to 10 times the height of the closest obstruction.
- **Temperature and relative humidity:** Temperature and relative humidity sensors should be located over an open, level area at least 10 m in diameter. The surface should be covered with short grass or another natural surface. These sensors should be located a distance of at least 4 times the height of any nearby obstruction, or at least 30 m, from large paved areas. Sensors should be protected (or shielded) from thermal radiation and ventilated.
- **Solar radiation:** In the Northern Hemisphere, sensors should be mounted on the southernmost side of the station to prevent exposure to shadows. Reflective surfaces and artificial radiation sources should be avoided.
- **Rain gauge:** Rain gauges should place as far away from obstructions as possible; ideally a distance equal to four times the height of the closest obstruction. The collector of the rain gauge must be in a horizontal plane, level, open to the sky, and above the height at which splashing rain and snow accumulation can influence the measurement.

Figure 3. Agroclimatic station linked to PRECIMED platform. Spain

For instance, in the case of using an Imetos weather station, a SIM card for the transmission of the data to the PSSL platform is needed. For this reason, the installation site needs to be covered by a good GSM/GPRS network.

- Before making the system working, there is a need to create an account at www.fieldclimate.com as administrator or user and insert the serial number of the station.
- The station can be connected to the PRECIMED platform by sending a special code: "!serial number 0 APN, user name, password!".
- The station is powered by a battery, with an intensity of 6 volts and rechargeable by a solar panel. To expose the solar panel to a maximum sunshine, the sensor block needs to be oriented to the North. The sensors block (air temperature, air relative humidity, global radiation and rain gauge) must be attached to the pod (provided with the station) at the height of 1.80 m and the wind speed sensor need to be attached at the height of 2 meters.
- Finally, accessing to the PRECIMED platform is possible to check the climatic data in real time. In the same way, the platform is registering data to send which might be used by the DSS.

2.1.2. Installation of soil moisture sensors

The use of soil moisture sensors for irrigation scheduling is becoming more common in irrigated agriculture, as they can provide robust data to determine the timing and volume of the irrigation. The quality of the data received depends on the proper installation of the sensors. If a sensor is not correctly installed, it will provide misleading information and result in inaccurate irrigation scheduling.

The crop type and the soil heterogeneity in depth and space have to be considered when installing soil sensors. Sensors need to be located in that depth where the majority of the root system resides and at the most representative sites of the irrigated field. Having soil sensors at various soil depths can provide data regarding changes in soil water and plant water uptake throughout the growing season. Early in the season, soils sensors should monitor one-third of the depth of the root zone, but at the peak of crop water use, they should monitor at least two-thirds of the crop root zone (Rix et al., 2020).

There are many commercial soil water sensors available, some examples are capacitance sensors and time-domain reflectometry-based (TDR) sensors. And there are some general aspects for the installation of all of them:

- Select a location that represents the majority of the crop growing conditions on the field. Sensor location is critical. Within-field variability in soil type and/or terrain elevation is common in many crop fields. If significant within field variability exists, more than one sensor should be installed based on management zones having uniform soil water storage characteristics. If the decision is to use only one sensor per field, the sensor should be installed at a location that represents most of the field conditions.
- Install the sensor in between two plants within the crop row.
- During sensor installation, avoid damaging the plants that will be in close proximity to the sensor.
- Ensure there is good sensor-to-soil contact.
- Avoid air pockets between the soil and the sensor.
- Avoid installing the sensor in a waterway.
- Check manufacturer's instructions for installations.
- Install soil sensors 20 to 30 days after planting.

2.1.2.1. Capacitance Sensor Installation Guidelines (Drill and Drop probe)

The Drill and Drop probe accurately measures soil moisture, temperature, and salinity. The probes are available in length of 30 cm through to 120 cm, with sensors by step of 10 cm. The measurement device includes the probe and a telemetry system. The installation of the probe in the soil needs to respect the following steps:

- **Step 1.** Before going to the field for the installation of the probe, there is a need to connect, in the laboratory, the probe with the modem, the satellite and the server for the storage of data. To do that, there is a need to insert, firstly, a SIM card into the modem and proceed to the configuration of the probe using "probe config software" that can be downloaded from the web. After a successful configuration, the system is ready to be installed in the field.
- **Step 2.** Make the hole in the soil between two healthy plants using a special auger provided in the installation kit, up to the deepest target depth for monitoring at about 0.50 cm from the dripper (Fig. 4A). Be careful not to open an oversize hole; air gaps will result in erroneous data
- **Step 3.** Fill the bucket with soil extracted from the hole. Mix with water and create slurry. Avoid particles such as small rocks and plant residues. Thick slurry might create air gaps close to the sensor. Thin slurry might crack more easily if the soil dries out, creating air gaps and preferential water flow. Pour the slurry up to one-third of the hole depth.

- **Step 4.** Install the probe in the hole previously confected (Fig. 4B). Shake probe firmly while inserting into the hole; this helps to remove small air gaps, especially for heavy soils. Insert probe fully into the ground.
- **Step 5.** Remove excess slurry. If necessary, insert a thin object through the slurry to remove air gaps. After removing excess slurry, put some dry soil on the topsoil to close the hole; this will prevent soil cracking and preferential flow of water through the hole (Fig. 4C).
- **Step 6.** In case the sensor can be damaged by the passage of agricultural machinery, protect the sensor head with a mesh. Try that the material with which it is protected is not waterproof and can modify the moisture of the soil (Fig. 4D).
- **Step 7.** Anchor the telemetry system in the soil. Connect the Drill and Drop probe to the telemetry system using the special cable provided with device (Fig. 4E).
- **Step 8.** The installation is completed and the device should be integrated in the PRECIMED platform through a SDI-12 data logger, and then configured to run in the corresponding DSS (Fig. 4F). If the probe uses a telemetry system to transfer the data to the server (Fig. 4G), the probe needs to be connected to the PRECIMED platform by the help of the platform developer (Odin Solutions).

Figure 4. Capacitance Sensor Installation

2.1.2.2. TDR Sensor Installation Guidelines

- **Step 1.** Open a pit using an engine-powered auger or using a tractor with shovel (Fig. 5A). The pit wall should be 5 to 8 cm from plants to avoid damaging the root system.
- **Step 2.** Measure the depth at which the TDR sensor (s) will be installed (Fig. 5B).
- **Step 3.** Insert TDR sensors horizontally with respect to the soil surface and perpendicular to the crop row (Fig. 5C).
- **Step 4.** Use the installation guide provided by the manufacturer to prevent sensor rods form bending and ensure that rods are evenly separated during installation (Fig. 5D). Sensor readings will be affected if rods get bent. Install sensors from bottom to top.

- **Step 5.** Repack soil using the same soil order/type extracted from the hole (Fig. 5E). Position cables on the opposite side of the pit where the sensor was installed to prevent preferential water low that could interfere with sensor readings.

Figure 5. TDR Sensor Installation in a pomegranate farm

2.2. Guidelines for sensor installation in greenhouse crops

2.2.1. Climate sensors, rain gauges, and dielectric sensors

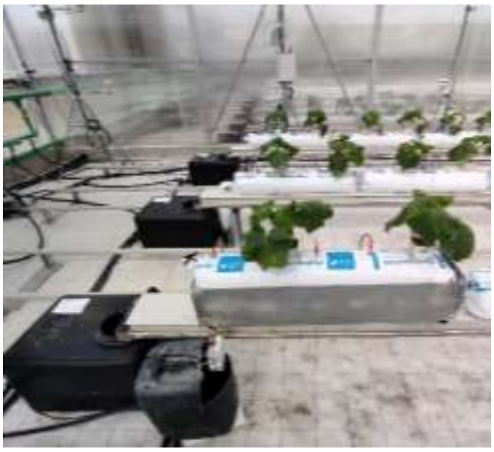
In greenhouse crops, sensors play an important role in detecting many parameters, such as climatic conditions, water supply etc., which are critical for plant growth and optimal qualitative and quantitative performance. Smart farming technologies, and precision agriculture help farmers make accurate decisions about their crops. Installation of microclimate control sensors equipped with temperature, relative humidity, and solar radiation sensors leads to real-time crop advisory services.

Greenhouse sensors for climate control should be installed inside the greenhouse facilities, as shown in Figure 6. These sensors record the temperature, relative humidity and solar radiation values inside the greenhouse compartment every 10 minutes. These data are stored in a recording system or in the cloud and can be retrieved at any time and used as the necessary inputs for the PRECIMED DSS to run properly. In addition, these sensors are likely to be used for the prediction of the conditions inside the greenhouse for the upcoming week, as PRECIMED DSS considers future climate data as inputs to predict future plant nutrient uptake.

Figure 6. Temperature (°C), relative humidity (%) and solar radiation (W m-2) sensors installed inside a greenhouse compartment cultivated with a soilless tomato crop

Rain gauges (Figure 7) can be built-in or stand-alone to collect data based on the irrigation and drainage nutrient solution volumes. They contribute to the detection of possible mismatches in the measured irrigation and drainage nutrient solution volume with the corresponding suggested values of the DSS. They appear in a variety of types and working models. In the PRECIMED DSS, crop transpiration is needed in order to estimate crop nutrient uptake. Crop transpiration is calculated as the result of the subtraction of the daily drainage volume from the initial volume used to irrigate the crop and is as follows:

$$Crop\ transpiration\ (Lm^{-2}) = Irrigation\ volume - Drainage\ volume \qquad \text{Equation (1)}$$



(a) **(b)**

(c)

Figure 7. Rain gauges installed inside the greenhouse compartment to measure the drainage (a-b) and the irrigation (c) volume imposed on a cucumber crop.

To calibrate the rain gauges, several inputs are needed for the DSS to run properly.

<u>Considering the crop irrigation setup:</u>

- The number of emitters used in each rain gauge must be determined. For example, in the PRECIMED DSS case 2 and 5 emitters were used in the rain gauge of the irrigation volume (Fig. 7c) and drainage volume (Fig. 7a), respectively.
- The number of the total emitters used in the hydroponic system must be determined
- The ml per irrigation and/ or drainage pulse must be determined
- The emitter flow rate (L/h) must be determined
- The cultivated area (m^2) must be determined
- The total number of plants must be determined

Considering the irrigation settings:

- The greenhouse light permeability must be determined
- The curtain activation if applicable, must be determined
- The solar radiation values for curtain expansion must be determined
- The curtain light permeability and time of activation must be determined

Considering the crop/health thresholds:

- The maximum EC must be determined
- The max and min irrigation and drainage variation (e.g. 30%) must be determined
- The dose (e.g. 0.15L/m2) must be determined

Another important sensor is a dielectric sensor for the control of the substrate characteristics. This type of sensor can be portable and fixed. They usually consist of several metal needles that are inserted in the slab and measure the dielectric permittivity of different types of growth media. They need a different calibration process according to the different substrate type. Dielectric sensors collect data about the moisture content (%, v/v), the electrical conductivity (EC, dS m^{-1}) and temperature (T, °C) values of the hydroponic slabs.

2.2.2. pH and EC sensors of irrigation and drainage nutrient solution

A pH and an electrical conductivity (EC) recording sensor are usually connected on the hydroponic head to record the values of the irrigation nutrient solution. It provides useful information to the end-user about the composition of the irrigation nutrient solution and the management of the irrigation process. The mean pH values in a hydroponic irrigation solution are mainly varied between 5.5-5.7, while the EC values depend to a great extent on the type of crop but mainly are varied between 2.1-2.6 dS m^{-1}. Moreover, there are portable pH and EC sensors (e.g. Hanna Instruments) that can be used on the field and can measure these values on-site using nutrient solution samples to confirm that the DSS decision.

2.2.3. Manometers

Three types of manometers are used in hydroponic irrigation system in order to manage the water volume that is used in a crop.

a) Hydroponic Head manometers

This type of manometer is connected on the hydroponic head to measure the quantity of nutrient solution that is prepared in every mixing event.

b) Manometers on stock nutrient solution tanks

This type of sensors is connected on the stock nutrient solution tanks. The use of these sensors could provide farmers with specific data regarding the volume of the nutrient solution applied in every irrigation event.

c) Manometers drainage tanks

The manometers that are connected to the drainage solution tanks aim to record the drainage solution volume and avoid overflow incidents. Specifically, when the volume of the drainages exceeds the overflow limit, the emptying process of the tanks is activated. In open hydroponic systems, the drainages are discharged into the environment, while in closed and semi-closed hydroponic systems, the drainages return to the hydroponic system in order to be further recirculated.

3. Recommendations on how to use the DSS based onsite location

3.1. DSS application in open field crops

The accuracy of methods using precision tools depends on a variety of factors including atmospheric, climatic, and weather conditions; crop and field conditions; and the analyses technique. Site characteristics can influence the choice of some production practices. For example, soil permeability may affect a producer's choice of irrigation system and the fertilizer application method.

Similar aspects must be taken into account when choosing for the proper approach for a DSS, as farm characteristics, sensor availability, costs or other aspects related to the IoT can make that the user choose among different possibilities.

According to this fact, the irrigation in open-field crops might be scheduled through the DSS with different approaches, like the one described in the irrigation protocol (section 1.1.) or for example, by a water balance method. For this reason, it is needed to follow the steps described below:

- Determine soil characteristics to obtain parameters as total available water (TAW) and readily available water (RAW):

$$TAW = 1000(\theta_{FC} - \theta_{WP})\, Z_r$$

where θ_{FC} is the soil water content at field capacity (mm), θ_{WP} is the soil water content at wilting point (mm) and Z_r is the depth of root zone (m).

θ_{FC} and θ_{WP} can be determined in soil laboratory or by the use of the soil water characteristics software developed by USDA-Agricultural service and the department of Biological systems Engineering, Washington state University. This tool can be used to calculate the correct indicative values of the soil physical characteristics taking into account its clay and sand contents.

$$RAW = p\, TAW$$

Where p is the average fraction of Total Available Soil Water that can be depleted from the root zone p values for different crops can be found in Allen et al., 1998.

- Obtain daily climatic data from an automatic weather station, for the calculation of reference evapotranspiration and effective precipitation: maximum and minimum temperatures, air humidity, wind speed, solar radiation and precipitation.
- Soil water content for the control of the daily water content.

Therefore, the main steps to follow for the development of an irrigation scheduling based on a water balance can be summarized as follow:

- Calculation of readily available water (RAW);
- Estimation of daily reference evapotranspiration (ET_0) obtained by an agro-climatic station;
- Numerical calculation of daily crop coefficients during the crop cycle (K_c);
    - Calculation of daily crop water use ($ET_C = K_C * ET_O$);
    - Estimation of net crop water use tacking into account the efficiency of irrigation system (ETc/Efficiency);
    - Calculation of effective rain (P) (mm);
    - Calculation of irrigation (I) (mm);
    - Calculation of daily change in water balance (P + I - Net crop water use);
    - Remaining available water in the soil taking into account the readily available water.

Note:

- The irrigation starts when, the RAW is depleted;
- When the remaining available water is positive means that the positive value need to be considered as drainage.

In general, independently of the method used, the main objective of the DSS is to present an irrigation recommendation which can fully satisfy crop water requirements and be respectful to the environment. This is done by means of applying just the water and nutrients that the crop needs and as it has been presented, through the use of the PRECIMED DSS, this action can be done with more accuracy. The result is that this kind of management can save not only water and nutrients but also time and energy, which means more profitable and sustainable farms.

3.2. DSS application in greenhouse crops

The necessary weather forecast inputs for the upcoming week such as T_{min}, T_{max}, and SR_{mean} should be obtained from official online sites or local weather stations, for the proper system operation and a reliable prediction. Alongside the weather forecast data, the farmer should also insert into the DSS the predicted irrigation and drainages volumes as shown in Figure 1. After, inserting all this data to the model, the DSS will provide the user with the upcoming weekly nutrient recipe that it is suggested according to the given data. It is important for the end-user to know the limits of the concentration for every macronutrient and micronutrient that is applied to the crop. The average composition of a nutrient solution for a soilless cucumber crop in the Mediterranean basis is given in Table 2.

Table 2. Average composition of a nutrient solution for the fertigation of soilless cucumber crops

$[NO_3^-]$ mmol/L	$[H_2PO_4^-]$ mmol/L	$[K^+]$ mmol/L	$[Ca^{2+}]$ mmol/L	$[Mg^{2+}]$ mmol/L	$[SO_4^{2-}]$ mmol/L
14.75	**1.25**	**6.20**	**4.15**	**1.60**	**1.30**

However, as already mentioned, the PRECIMED DSS is strongly related to daily solar radiation and therefore daily temperature regimes, which means that in case of extremely low or high temperatures or solar radiation values recorded in a day due to extreme climatic conditions or even a sensor malfunction, the final nutrient recipe recommendation may lead to wrong decisions.

Therefore, a limit of 50% variation of the standard nutrient elements (Table 2) is suggested. In case the DSS provides the end-user with a nutrient recipe recommendation that is 50% above or below the threshold values of each element, the farmer should consider a sensor malfunction or an error of PRECIMED DSS in daily nutrient calculations. Under these circumstances, the farmer should use the nutrient recipe of the previous seven days.

4. Guidelines for installation of fertigation system

4.1. Features of irrigation and fertilization system for open-field crops

4.1.1. Drip irrigation

In temperate zones with scarcity of water resources, the use of drip irrigation systems is widespread in fruit, citrus, vine and horticultural crops.

Drip irrigation is a method that allows the optimal application of water and fertilizers in agricultural systems, especially in arid zones. The applied water infiltrates into the soil, directly irrigating the area of root zone through a system of pipes and emitters.

Some of the advantages of this system are the following:

- It reduces significantly the evaporation of water in the soil.
- It allows to fully automating the irrigation system, with the consequent savings in labour. The control of the application doses is easier and more complete.
- Due to the maintenance of high humidity in the bulb carried out by the emitters, it allows the use of more saline waters for irrigation than surface and sprinkler irrigation systems.
- It has an easier adaptation on irregular, rocky or steep slopes.
- It reduces the proliferation of weeds in non-irrigated areas
- It allows the controlled contribution of nutrients with the irrigation water without losses due to leaching with the possibility of modifying them at any moment of the crop, that is to say, it is the system most adapted to fertigation.

Parts of the installation (Fig. 8):

- Pumping group: to supply the adequate pressure and flow to the installation. All pumps must work close to their maximum performance, which is reached only in a narrow range of flow that will be the criteria used to select the type of pump. This information will appear in the pump operating curves that must be supplied by the manufacturer in their technical catalogues. Regarding the diameter, in general, it is recommended that the pump be installed as centred as possible in the well hole so that the pump is surrounded by water around its entire perimeter, and that there is a minimum lateral distance between the perimeter of the pump and the inner wall of the well.
- The head of the installation: which includes a set of devices for treating, measuring and filtering water, as well as fertilizer injection devices. Basically, three types of filters can be used in drip irrigation systems, depending on their filtering function:
    - Hydrocyclone filters, used to separate the heavier particles that the water carries in suspension, such as the sand present in the flow.
    - Sand filters, to retain the clay particles and organic matter present.
    - Mesh filters and ring (or disc) filters, widely used, especially for water flows from wells.

Another component of the head is the fertigation equipment. Fertigation is a technique that allows taking advantage of the drip irrigation system to simultaneously apply fertilizers that are dissolved in the current with the water. This allows savings in fertilizers, since water and fertilizers are applied localized in the root zone of the plant, and better assimilation, due to the high moisture content of the soil that allows the dissolution of the fertilizer, as well as speed of action and economy for the distribution of fertilizer. On the other hand, the fertigation equipment, in addition to water and fertilizers, can be used to inject herbicides, fungicides and insecticides.

Figure 8. Overview of an Irrigation system

- The pipe distribution network: which is formed on the one hand by the main and secondary distribution lines that are usually buried, and on the other hand, the dripper branches that run along the surface of the land through the rows of crops for the discharge of water.

- The emitters or drippers: which are the elements in charge of applying the water to the plants and which are inserted in the dripper branches at every certain distance from each other, generally coinciding with the position of the plant. Self-compensating drippers deserve special mention, which are very useful when the pipe branches where the drippers are installed are very long and can present a large variation in pressure between the beginning and the end of the pipe, or in rough terrain with much unevenness. These emitters offer a fixed flow within a more or less wide range of pressure. The utility of these drippers lies in the ability to homogenize the irrigation along an irrigation line, since the last emitters of the line normally have a lower pressure than the first ones due to the pressure drop due to friction of the water with the pipeline.

According to the characteristics of the farm; size, type of terrain, soil type, crop cultivated, etc. there is the possibility of using different irrigation equipment, so the farmers have to choose the one that better fits their requirements. Below, there are some farm real-case scenarios that use different irrigation systems due to their characteristics, which differ mainly on the volume applied by the drippers and the number of dripper lines, which means that irrigation is managed differently.

4.1.2. A pomegranate farm using PRECIMED DSS. CEBAS-CSIC Spain

The farm is located at the experimental station from CEBAS-CSIC, in Santomera, Murcia (38° 6'N, 1° 2'W). Trees are own rooted 10-year old Mollar de Elche. Trees are spaced following a 3 m x 5 m pattern and the total area cultivated with this variety is 0.8 ha.

Irrigation was conducted daily at sunrise and sunset, using a drip irrigation system, with a lateral irrigation line per tree row and six drippers per tree spaced 50 cm between drippers, set at a rate of 2.2 L h^{-1} (Figure 9).

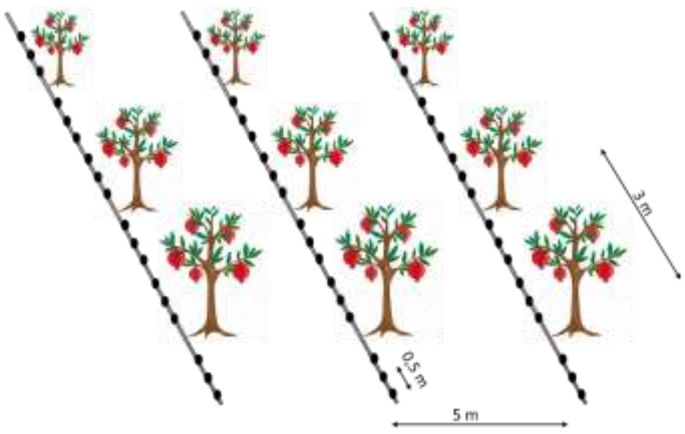


Figure 9. CEBAS Irrigation system scheme

The farm has its own well. The plot is divided into 4 irrigation sectors, whose dimensions and distribution is shown in Figure 10.

The emitter used is a flat self-compensating dripper integrated into the branch. The branches and branch pipes used were made of high-density polyethylene (PE), while the main pipe and the well pipe were made of polyvinyl chloride (PVC). The main pipeline is buried in a trench 1.2 m deep.

The irrigation head is made up of a set of elements such as those described above and chosen based on the flow rate required on the selected farm. In addition, for the correct operation of the motor in the irrigation house, a pumping panel is installed. The elements to regulate the flow of water to the different sectors are electro valves. The electro valves are activated by an irrigation controller that is also located in the irrigation station.

Figure 10. Irrigation station and PRECIMED Experimental set up

4.1.3. A citrus farm using PRECIMED DSS. INRAA Algeria

The irrigation system of citrus crop in this pilot farm, is a drip irrigation system (Fig. 11). Each row of citrus includes two lateral dripper lines in a distance of 2.50 m. Each tree includes 4 drippers (2 drippers per dripper line) including, each one, a water flow of 8 liters per hour. The distance between the dripper is 1 m.

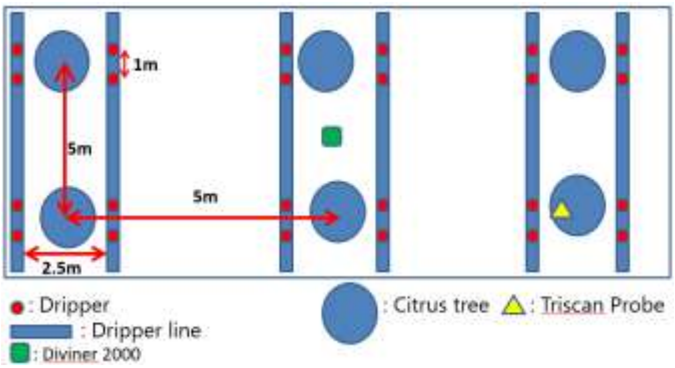


Figure 11. INRAA Irrigation system scheme

The area of the plot is about 4.16 ha, divided in two sectors. Water comes from a well with a depth of 160 m and equipped with an electrical pomp of 25 CV and a flow of 30 m^3 per hour. The well is connected with the irrigation system.

The measurements achieved in the field showed that the duration of irrigation varied from 3 hours during the cell expansion stage with an irrigation dose of 10.39 mm, and then the irrigation duration last 7 to 9 hours during the full development of fruits with an irrigation dose estimated at 33.41 mm. The irrigation is scheduled according the personal experience of farmer. Regarding the fertigation system, a tank of 1000 L for nutritive solution is connected to the irrigation system network.

4.2. Features of irrigation and fertilization system for greenhouse crops

4.2.1. Irrigation scheduling in greenhouse crops

An irrigation system would be described as a network of stable tubing connected to emitters settled to irrigate a certain area.

a) Principles of efficient irrigation:

- Adequate amount of water for the plants.
- Efficient and uniform use of water.
- The time of water application should meet the requirements of the crop and weather conditions.

b) An efficient irrigation system must be featured by:

- Design and installation to transfer efficiently the water needed for the plants at the right time.
- A timer for the irrigation system must be set for a certain time limit or connected to a rain gauge.
- Proper function of the irrigation system to reduce water waste. The irrigation system should be adapted depending on the needs of the plants and the weather conditions. (Efficient irrigation for water conservation: Guideline for water efficient urban gardens and landscapes).

c) The technical layout of the irrigation system:

- Water source (tank)
- Hydroponic head and mixing tank for the nutrient solutions.
- PE pipe circuit.
- Emitters.
- Drainage tank
- Irrigation nutrient solution.

The hydroponic head unit controls the whole process of producing fresh nutrient solutions. Firstly, a nutrient solution is produced using stock solutions that are in a concentration of approximately 100-200 times higher than that supplied to the plants. Two stock tanks are involved for fertilizers and one more stock tank for acid. Nutrients from the fertilizer tanks are added to the mixing tank of the main unit based on the desired EC and then tap water is added to dilute the nutrients, while acid to manage the preset pH in the new nutrient solution. After this process, irrigation can start or the nutrient solution is stored in nutrient solution tanks. The irrigating nutrient solution is applied to the crops using a polyethylene pipe circuit. The irrigation system should be properly installed so that all emitters in the same pipe circuit have the same performance (e.g. drip) and provide the desired amount of water at certain points. In drip irrigation, small emitters are used to deliver a constant amount of water at a low pressure and flow rate. However, it is worth mentioned that drip irrigation needs regular maintenance and careful operation. To improve plant irrigation, 4 to 5 emitters could be used in each hydroponic slab (perlite and rockwool) with a flow rate of 2 Lh^{-1}. Emitters are a piece of equipment that fits into a pressure pipe and release water in the form of a drop. The choice of irrigation system must be made depending on the type of crop, the microclimate of the greenhouse, and the type of growth medium. The dose and the frequency of the irrigation depend on the solar radiation intensity, plant growth stage, and the fraction of drainages. The main parameters that affect irrigation scheduling are solar radiation intensity, air temperature, relative humidity, and crop substrate, which are taken as a support tool to make decisions on irrigation programs. For optimum plant irrigation is suggested the 'solar radiation method'. According to this method, the frequency of irrigation is based on measurements of internal and external greenhouse solar radiation. Moreover, there can be a combination of two irrigation scheduling methods, the solar radiation method, and the time clock scheduling to secure that the hydroponic slabs contain enough moisture during the day. For instance, considering solar radiation as the value of irrigation scheduling, it is recommended to activate the irrigation events when 1MJ m^{-2} of accumulated solar radiation has been intercepted. A common irrigation practice during the summer period is to increase irrigation frequency up to six times per hour. Furthermore, irrigation may be delayed during periods with low radiation on cloudy days.

The weather forecast predictions affect also the irrigation EC. When the humidity is increased, the EC should be gradually changed. On cloudy days, the EC of the irrigation nutrient solution may be increased. In optimal weather conditions (sunny days), EC must be decreased as opposed to cloudy days. The irrigation pH may range from 5.5 to 6.5 while in the drainage solution should not exceed the range of 6.7-6-8.

4.2.2. Fertilization in greenhouse crops

The features of the fertilization system may include the following aspects:

- The nutrient solution must have adequate concentrations of the macronutrients such as N, P, K, Ca, and Mg to be balanced and meet the needs of the plants. In smaller but significantly needed concentrations are found the micronutrients.
- An overall analysis of the tap water used in fertigation is vital. Generally, it is suggested a nutrient solution analysis per week. Each time the water source is changed, the analysis should be redone.

- The EC of the nutrient solution affects plant growth. The ‘salinity effect’ should be limited in the nutrient solution. A problem found in warm and low-humidity days is that essential quantities of water from the nutrient solution are rapidly absorbed by the roots. Lower EC could seriously affect the yield and health of plants, but higher EC could delay the uptake of nutrients.
- The temperature of the nutrient solution should meet the ambient air temperature. On warm days, when the atmospheric temperature is high, the contact of the roots with the nutrient solution that has a lower temperature could be harmful to plants, resulting in stress conditions. The roots of the plants cannot absorb enough water and nutrients to meet the needs of top parts (new leaves) of the plants that are strongly exposed to sunlight and higher temperature when the temperature of the plant roots is low or generally below ambient air temperature. This condition if repeated could decrease significantly plant growth. On the other hand, very high nutrient solution temperatures could lead to limited oxygen flow.

4.2.3. Maintenance

A regular service must be performed for the maintenance of the irrigation system.

- Emitters should be checked and replaced when needed.
- Checks of the main hydroponic lines for breaks or leaks.
- Checks in the pressure regulators, controllers, and sensors and calibration if necessary.
- Constant maintenance of plants is necessary, removing of damaged parts.
- It is recommended to flush regularly the irrigation system to remove algae and keep the emitters clean and unblocked.
- If appropriate, inspect water pumps and maintain tanks.
- Routine inspections and a maintenance plan will lead to a well-functioning irrigation system.
- It is suggested once a week to measure the substrate moisture and electrical conductivity.
- Cleaning of the climatic sensors
- Cleaning of the rain gauges sensors
- Sensor calibration
- Battery charging

5. Guidelines to increase water and fertilizers use efficiency

5.1. Water and Nutrient Use efficiency in open-field crops

In the Mediterranean region, irrigated agriculture contributes 75% to the final production. The demand for water and for fertilizers is increasing, but so is the demand for water use efficiency (WUE) and for nutrient use efficiency (NUE). Increasing resource-use efficiency while reducing yield gaps can be addressed by suitable agricultural management practices. In this sense, one of the main aims of PRECIMED is to optimise the sustainability of agriculture by using Precision Irrigation techniques, adopting and implementing new water and nutrient management practices. Therefore, for the improvement of WUE and NUE, the current trend of fertigation management implies:

- To determine new **deficit irrigation strategies** to mitigate the effects of water shortages maintaining plant and yield quality even when low quality irrigation water is used. Deficit irrigation can be applied either as sustained deficit irrigation, applying water at a constant fraction of potential evapotranspiration through the season, or as regulated deficit irrigation (RDI), in which water deficits are imposed only at certain crop developmental stages, the duration of the water stress period during each growth phase being very important. The usefulness of RDI practices is strongly dependent upon avoiding water stress during those periods in which marketable crop yield is particularly sensitive to water stress.
- To reinforce research and development in **irrigation scheduling** through the use of indicators based on soil and plant water status. Precision irrigation is technologically feasible through the use of different sensors, probes, and decision support systems. Today, there is a wide variety of potential solutions available on the market ranging from the simplest based on handheld sensors to the most complex using satellite imagery. Among the sensors used to obtain soil moisture, capacitance and TDR sensors (described in section 2 of this document) stand out. The use of wireless sensor technologies to improve WUE in irrigated agriculture is on the increase. More often, a series of wireless sensors are used to monitor various parameters in the field, for example soil moisture and weather data. The sensor networks may also have actuators that can be used to automate the irrigation system.
- To advance our knowledge of **water relations and the eco-physiological behaviour** of species deemed to be of special socio-economic interest (citrus, fruit trees, vegetables, etc.).
- To study the use of **non-conventional water resources** (reclaimed, desalinated, saline waters) for agricultural irrigation. The use of this type of water is an alternative water resource, which allows reducing the risks of environmental contamination, since they are an important source of nutrients for plants and reduce the use of fertilizers. However, they have a high concentration of salts. Studies have to be carried out on the efficiency of the use of nitrogen and water, as well as the effect of these reclaimed waters on the quality of the plant and the fruits.

At field level, to increase the water and nutrients use efficiency, the following recommendations must be followed:

- Control the quantity of water delivered in the plot: Installation of water meters at the beginning of the plots to be irrigated.
- Ensure a homogenous distribution of water in the plot: Evaluate the uniformity of the distribution of water. If there is a low uniformity coefficient, there is a need to detect the problem associated like clogging from sediments or other materials, the control of flow rate of the drippers and the water pump.
- Control of soil water content to evaluate the impact of irrigation rate.
- Ensure the maintenance periodically of drip irrigation system to make it working correctly: Periodic flushing to prevent clogging, Chlorination, water sampling to detect the causes of clogging; replacement of the tape and drippers damaged.
- Control electrical conductivity of soil using Drill and Drop probe to optimize the fertigation.
- Control the pH of the soil to define the appropriate and timing of fertilizers to use.
- Soil analysis each year to develop an adapted fertilization plan.
- Foliage analysis defines the additional fertilizers.
- And last but not least, there are some cultural tasks that can also favour the water and nutrient use efficiency, such as increasing the level of organic matter in the soil, the use of beneficial microorganisms, mulching, or planting species adapted to the environment.

5.2. Water and Nutrient Use efficiency in greenhouse crops

In hydroponics the water use efficiency (WUE) is greater as the nutrient solution goes directly to the roots of the plant and enables the plant to use it properly for optimal growth. One significant aspect in terms of WUE is the design of the irrigation pipe system which should have a proper size to deliver water at the desired pressure and flow rate. Moreover, to schedule the irrigation events and hence optimize WUE, the substrate water-holding capacity should be taken into consideration. The substrate water-holding capacity and the volume of the roots affect the frequency and the dose of irrigation scheduling.

High-quality water used to fertigate a crop results in a more efficient irrigation enabling the recirculation and reuse of drainages, and therefore increases WUE in such systems. In the case of low-quality water, the drainage solution obtained after the irrigation of the crop has to be discharged into the environment to assure that no salinity issues will occur. In hydroponic systems, the percentage of drainage should vary from 20 to 30% to maintain EC in the substrate in optimal levels. In case of higher drainage volumes, the irrigation schedule must be reconsidered to achieve the most efficient use of water and nutrients since water and nutrient depletion affect both the farmer and the environment.

A precise control of the irrigation system could lead to an efficient use of water and nutrients by minimizing losses. Careful monitoring of fertigation and equipment maintenance leads to effective use of water and nutrients. The frequency and duration of irrigation are important parameters when referring to water use efficiency. A method of increasing WUE is to increase frequency while decreasing the dose of the nutrient solution applied to the crop.

6. Common fertigation problems and seasonal fertigation adjustments

6.1. Open-field crops

Some of the most common problems related to fertigation in outdoor crops are the following:

- Fertigation can produce an excessive increase in the salinity of the irrigation water, so the nutrient solution needs to be applied in the appropriate dosage.
- Clogging of lines and emitters may become a problem if not managed appropriately. To solve this problem it is recommended to use emitters designed to reduce clogging when possible. To prevent precipitation and clogging, water-soluble fertilizers with near-neutral pH and a low salt index are needed. There is risk for precipitation in fertigation systems when using fertilizers with calcium or magnesium. Growers and operators should ensure compatibility between fertilizers before use.
- In the application of deficit irrigation strategies, fertigation can be negatively altered if the timings and dosage are not calculated properly.
- Water excess in the bulb might stress the crop. These conditions affect strongly the absorption of water and fertilizers and can attract some fungal diseases. This implies the installation of drainage network when necessary.
- Leaching of fertilizers due to the excess of rain in winter.
- Irrigation system not controlled / evaluated during the start of irrigation campaign.
- Organic fertilizers, globally, absents.

Application of fertilizer recommendations without achieving soil, water, and plant analysis. Regarding seasonal fertigation adjustments, fertigation allows farmers to change their program during the growing season, adjusting it to suit fruit, flower, shoot and root development. A program should be developed on the basis of leaf and soil analysis and tailored to suit their actual crop requirements. However, in case the fertilizers are not completely dissolved and mixed prior to injection into the system, this may result in varying concentrations applied or blockages within the system. Suitable anti-siphoning valves or non-return valves should be installed where necessary to prevent backflow or siphoning of water, fertilizer solution, chemical solution etc. into fertilizer tanks, irrigation supply and so on. In addition, during the irrigation season it is important to monitor:

- pH effects over time in the root zone
- Soil temperature effect on nutrient availability
- Corrosion and blockages of outlets
- Reaction with salts in the soil or water

6.2. Greenhouse crops

Common irrigation problems that are found in regular inspections:

- Blocked emitters or malfunctioning
- Wrong number of nozzles in the same irrigation line
- Incorrect irrigation scheduling (more irrigation events than needed)
- Not suitable pressure for the effective function of the system
- The application lacks of uniformity and precision
- No proper mixing of fertilizers
- Low-quality saline water in hydroponics results in water discharge or desalinization
- No sensor and climate control. Control of fertigation permits in-season nutrient adjustments as the plants have different nutrient needs at each growth stage
- high percentages of drainage (>40%)

7. Inspection for better control

7.1. In terms of irrigation system:

- To evaluate the uniformity of irrigation periodically, to have an idea about the status of irrigation system globally and the status of drippers. In case of heterogeneity, it will be necessary to do a deep inspection of irrigation system to detect the causes of irrigation heterogeneity like leaks or clogging from sediments or other materials.
- To evaluate the status of the plants related on its growth to detect if the distribution of water is homogeneous at the level of the plot.
- Periodically visually inspect the irrigation water in the field. If not using auto flush fittings, open the ends of the drip lines during irrigation to help remove any buildup of particles and other debris that can lead to clogging.
- To perform routine cleaning and/or replacement of pump filters to reduce the accumulation of sediment and other debris.
- To make sure connections are secure at every valve control zone. If the fittings are damaged or broken, replace them right away to prevent losing water and compounding damage
- To keep a record of the date, location, and number of visual inspections made and a description of what was observed.
- To check that the irrigation system pressure works within the established range

7.2. In terms of the maintenance of the sensors, the following actions need to be performed periodically:

A. Automatic weather station:

- Cleaning of sensors
  - Sensor for solar radiation: every month, clean it with a soft, clean and damp cloth. If necessary, adjust the sensor to ensure its level.
  - Rain gauge: Every week, there is a need to inspect the rain gauge and, if necessary, clean it.
- Solar panel:
  - It needs cleaning every week with a soft, clean and damp cloth.
- Calibration and changing of sensors:
  - Solar radiation sensor: calibration every 3 years.
  - Humidity/temperatures sensor: changing every year.
- Battery:
  - Continuous control of the intensity of the battery. When the intensity of the battery reaches values lower than 5V, it is necessary to proceed with its replacement.

B. Capacitance probe (Drill and drop probe):

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.

- Periodically (at least yearly) check electrical ground connections.
- Battery
  - The battery of the device has an intensity of 14,4V. The telemetry system and the probe stop to work respectively at 11 and 8.5V.
  - There is a need to control continuously the battery and to proceed at it changing when the battery reaches values around 11V.
  - To avoid the problem of the discharge of the battery, it is recommended to use a Drill and drop device working with the use of solar panel

7.3. In term of soil salinity

The Drill and Drop probe measures volumetric water content which might be sufficient for the monitoring of trends in changing soil salinity. In many cases, however, it is important to be able to relate VWC to soil Electrical Conductivity (EC) to use it with accuracy for the monitoring of soil salinity and to optimize the fertigation.

7.4. In greenhouses

In greenhouses, it is suggested a regular inspection of the irrigation system to prevent or correct any possible malfunctions. The inspection for better control includes:

- Collecting data (irrigation/drainage volumes) on the irrigation lines using rain gauges to evaluate system's performance.
- Periodically, visually check of the health of plants and the humidity of the substrate.
- Checking the function of the drippers, in order to notice any heterogeneity in the water content of the substrate.
- Verify that the sensors and other parts of the irrigation system are working properly and inspect the system during operation.
- Whenever the water source is changed, a water analysis should be done. Otherwise, the available water should be checked occasionally.
- pH values should be checked in both irrigation and drainage solutions. When the pH values are higher in the draining nutrient solution, then NH_4^+/NO_3^- must be adjusted by adding NH_4^+.
- Last irrigation event should be done about 1.5-2.0 hours before sunset.
- Irrigation with warm water (~18.0-19.0 °C) to enhance the nutrients movement to the fruits.
- About 2 hours before the first irrigation, the temperature of the greenhouse can be decreased, to achieve a better distribution of the necessary nutrients to the fruits.
- Irrigation of approximately 100-200 ml per plant and irrigation event. The first and the last irrigation events are 200ml, and the intermediate 150ml using solar radiation models.
- Use of humidity sensors or weight of the substrate to determine the water content of the hydroponic slab. Generally, the desirable water content of the substrate is about 70% v/v for rockwool.
- Substrate water content in the morning should be 65% v/v and 75%v/v around 11:00 a.m.

8. Other practical tips

Some practical tips suggested for recognize some mineral deficiencies in the crops:

- *Nitrogen Deficiency Symptoms (https://docplayer.fr/65886991-Fertilization-des-agrumes-en-algerie.html)*

- Old leaves are yellow;
- Veins are yellow
- The foliage is senescent, the leaves fall;
- Low production.

- *Symptoms of phosphate deficiency (https://docplayer.fr/65886991-Fertilization-des-agrumes-en-algerie.html)*

- Leaves are small and thin
- Early fruit drop;
- Weak fruit jus and very acid.

- *Potassium Deficiency Symptoms (https://docplayer.fr/65886991-Fertilization-des-agrumes-en-algerie.html)*

- Old leaves become large, with yellow sides and tips;
- Small fruits with a thin skin;
- Early fruit drops;
- Low yields and sugar content

Some practical tips suggested for the optimum irrigation scheduling in a hydroponic crop are:

- Plants cannot properly absorb the nutrient solution when the EC of the drainage solution is very high (twice as large as the original).
- The EC values in the beginning of the crop tend to be higher than those in the reproduction stage. A decrease in irrigation EC value promotes fruits growth.
- If the drainage EC values are higher than 4.0 - 4.5 dS m^{-1} in a soilless cucumber crop, the EC values of the irrigation nutrient solution must be decreased.
- When plant biomass increases and the plant gains height, more nitrogen is needed to maintain the plant in a standard height (e.g. for cucumbers up to 2.20m).
- The nutrient recipe should change when the plant is stressed and has no proper number of leaves.
- NH_4NO_3 should be increased when the leaves or the fruits are smaller than the marketable size. On the contrary, the end-user may need to add K2SO4 to balance a possible anomaly in increase of the fruit size. The suggested quantity of NH4NO3 and K2SO4 is 4kg and 5kg, respectively.

Some tips regarding the morphological characteristics of the plants that the farmer must observe frequently are as follows:

- In case the stems of the plant are soft and easily breaking, then it is due to either high EC or low nitrogen values. This can be solved by adding more NH4NO3 in the nutrient solution. However, excessive increase in nitrogen levels increases the risk of botrytis infection.
- Straight leaves and leaf curling is not desirable.
- Vivid tendrils are a sign that the plant is in a good condition.
- If there is no plant bloom, then there was either over-irrigation or lack of water.
- Leaf and stem color is a sign that the plant is in a good condition.
- Wilting top reveals a lack of moisture. When leaves of the top part of the plant (new leaves) have a light color then irrigation events should be minimized while increasing K fertilization.
- Small and thin fruit indicate a lack of nitrogen, which is managed through the addition of NH_4NO_3. Fruit thinning should be done to avoid fruit problems. If a production delay is desired, then the greenhouse temperature must be reduced.

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