Deliverable 2.1

Project Acronym: PRECIMED

Project full Name: Precision Irrigation Management to Improve Water and Nutrient Use Efficiency in the Mediterranean Region

[Assessment of pilot farms for the design of the PRECIMED DSS (M22)]

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27/07/2021	CEBAS-CSIC M.Fernanda Ortuño	Revision	Approved

Contents

Summary

The deliverable [**D2.1** – Assessment of pilot farms for the design of the PRECIMED DSS (M22)], focuses on the assessment of pilot farms, by identifying the requirements of the farms and the farmers, analyzing nutrients' and water availability management in the context of climate change, taking into account the impact of irrigation technologies on the productivity of water and fertilizers, and finally defining the most interesting system suitable for each one of the pilot farms included in the assessment, concerning the quality and the number of sensors required to fulfill each case study's needs.

The main stakeholders for PRECIMED are the farmers, cooperatives, and agricultural players based in the Mediterranean basin with the main characteristics of erratic rainfall, mild temperatures, irregular topography, and nearness to large water bodies. In this area, farming is intensive, highly specialized, and varied in the kind of crops raised. PRECIMED will develop the pilot activities in the main Mediterranean farm types (orchard/vegetables/fruits trees/viticulture and greenhouse/open fields farming) counting with farmers from the design phase with different size, soil, and climate conditions of holdings. Farmers need to improve the holdings´ resource efficiency.

Introduction

Aims: The main aim of this task will be the identification of the requirements of the farms and farmers. Approach: Different meetings at the start of the project will be held between the owners of the farms where the pilots will be installed and the development team.

Depending on their needs and concerns, different additional meetings with other types of stakeholders will be held (farmers, policymakers, agricultural services/product providers, etc.). Based on this the different scenarios to develop the DSS will be identified (M6). During the development of the DSS (WP3) an intermediate prototype will be tested by the farmers and presented to other stakeholders (M18). Based on the results from the 1st intermediate prototype and the feedback from farmers and stakeholders the final demonstration prototype will be re-designed and presented to farmers and stakeholders (M30).

Pilot farms in Greece

Farming scenario 1: Cucumber production in a commercial greenhouse

Cucumber Greenhouse (Larissa, Greece)

SITE

The "Agroktima Kalliantzis" is a commercial greenhouse facility located in Pyrgetos, Larissa, in northern-central Greece (39^0 55′ 12′′N; 22^0 35′ 27′′E), (Fig.1)

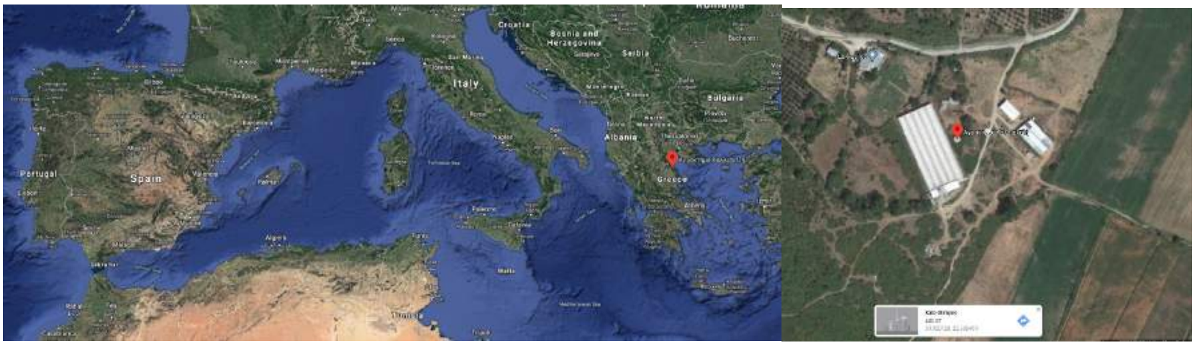

Figure 1. Location of "Agroktima Kalliantzis"

CLIMATE CONDITIONS (inside and outside the greenhouse)

The minimum and the maximum temperatures of the area are registered in January and July, and their average values over the last 5 years are -4^{0}C and 37^{0}C. Inside the greenhouse, the minimum temperature can reach 13^{0}C (registered during January) while the maximum 31^{0}C (during July).

GREENHOUSE AND PLANT MATERIAL

The greenhouse (Fig.1) has an area of 0,5 ha, it is of arched type, it has 5 sections and a polyethylene cover with polycarbonate on the gables and glass on the sides. The cultivated plant is cucumber, cultivar Columbia (Fig.2), done in two cultivation periods: the first one starts in February and ends in July (total duration: 160 days), and the second one starts in August and ends in January (total duration: 180 days). Plants' density is 1,8 plants/m^2.

The pilot greenhouse has a hydroponic system with the use of rockwool as substrate (soilless). The greenhouse is equipped with:

a) heating system
b) natural ventilation (roof vents)
c) forced ventilation
d) fan and pad system
e) thermal screen

Figure 2. Cucumber plant

Figure 3. Heating system (floor pipes, grow pipes) and Cooling system (wet pads)

IRRIGATION AND FERTILIZATION MANAGEMENT

The hydroponic system is open and the percentage of drainage rate is 35%. The greenhouse irrigation system is divided into 5 sections of 1000 m^2 each. The irrigation system is equipped with drippers every 0,25 m and has a flow rate of 2L/h. The system is controlled by a central automatic controller. Irrigation scheduling is based on solar radiation intensity and plants' growth stage. The irrigation doses are scheduled based on time-program and measurements –mainly of solar radiation intensity. More specifically, measurements of solar radiation intensity, air temperature, and relative humidity and crop substrate volumetric water content are taken as a support tool to decide on irrigation.

Irrigation is more frequent during warmer-sunny periods, specially during the mid-day, when plant-water demand is higher.

The dose is usually a little lower during the first crop stage and then it is constant. Lower doses in more frequent applications are preferred over "higher doses less frequently". The nutrient solution in the root zone is kept as close as possible to the target (initial nutrient solution).

Also, since in this greenhouse fertigation and not just irrigation is performed, an effort is made to optimize irrigation scheduling, as any reduction of irrigation water use, will result in a reduction of the use of fertilizers.

Concerning the fertilization, the composition of the nutrient solution is different depending on the stage of cucumber cultivation. The following table presents the basic recipe for nutrient solution synthesis at different stages of cucumber growth, as it is usually applied by local growers.

Table 1. Recommended concentrations of nutrients in the nutrient solution administered in hydroponic cucumber cultivation, at different stages of plant growth

		Transplanting	Flowering – Start of peaking	Start – End of peaking
EC	dS/m	2,50	2,20	2,00
pH opt		5,60	5,60	5,60
[K]	mmol/l	7,10	7,00	6,00
[Ca]	mmol/l	4,25	3,50	3,35
[Mg]	mmol/l	2,25	1,50	1,25
[NH_4]	mmol/l	1,00	1,25	1,00
[NO_3]	mmol/l	14,6	14,0	12,20

WATER QUALITY AND AVAILABILITY

Irrigation water has a good quality, with pH= 8 and EC= 0,38 dS/m^{-1}. Therefore, there are no salinity issues or other problems related with the irrigation water.

In relation to its availability, irrigation water comes up from private drilling, thus water is available on demand. The total irrigation annual requirements amount to around 18,000 m^3/ha.

HISTORICAL YIELD

The annual production is about 25 kg of cucumbers per plant, that is about 450 tons per he per year. 95% of the production is classified in Class A and the rest 5% is classified in Class B quality categories.

FIELD ACTIVITIES related to fertigation management

The following is an indication of the basic daily activities that take place in the greenhouse in relation to the fertigation management:

- Setting of irrigation scheduling program (doses and frequency)

- Preparation of the stock solutions (100 times concentrated nutrient solution) in the two of the four tanks used for the preparation of the nutrient solution

-Preparation of the tank used for pH control of the nutrient solution and for the pre-treatment of the water used for fertigation

- Sensor's (solar radiation, pH, EC, substrate volumetric water content) checking and maintenance

- Measurement of the percentage of drained nutrient solution in different sampling positions

- Measurement of the volumetric water content of the substrate in different sampling positions

- Measurement of the electrical conductivity and pH of the irrigation and drainage solution at different sampling positions.

ANNUAL CONSUMPTIONS

An indication of the quantity of the fertilizers used per year in the pilot case study for the 0.5 ha covered is given in Table 2.

Table 2. Fertilizers used per year

Fertilizer	Amount (Kg)
Potassium Nitrate	5475
Calcium Nitrate	6425
Magnesium Nitrate	1300
Magnesium Sulfate	1750
Potassium Sulfate	550
Ammonium Nitrate	440
Phosphoric Acid	3045
Nitric Acid	70
Iron Chelate	200

Farming scenario 2: Tomato production in a pilot greenhouse

Tomato Greenhouse (Volos, Greece)

SITE

The “Agroktima Velestino” is an innovative hydroponic greenhouse placed in Velestino, at the farm of the University of Thessaly (Fig. 4), in Volos, latitude 39º 22΄, longitude 22º 44΄ and altitude 85 m, on the continental area of eastern Greece, (Fig.4 and Fig.5)

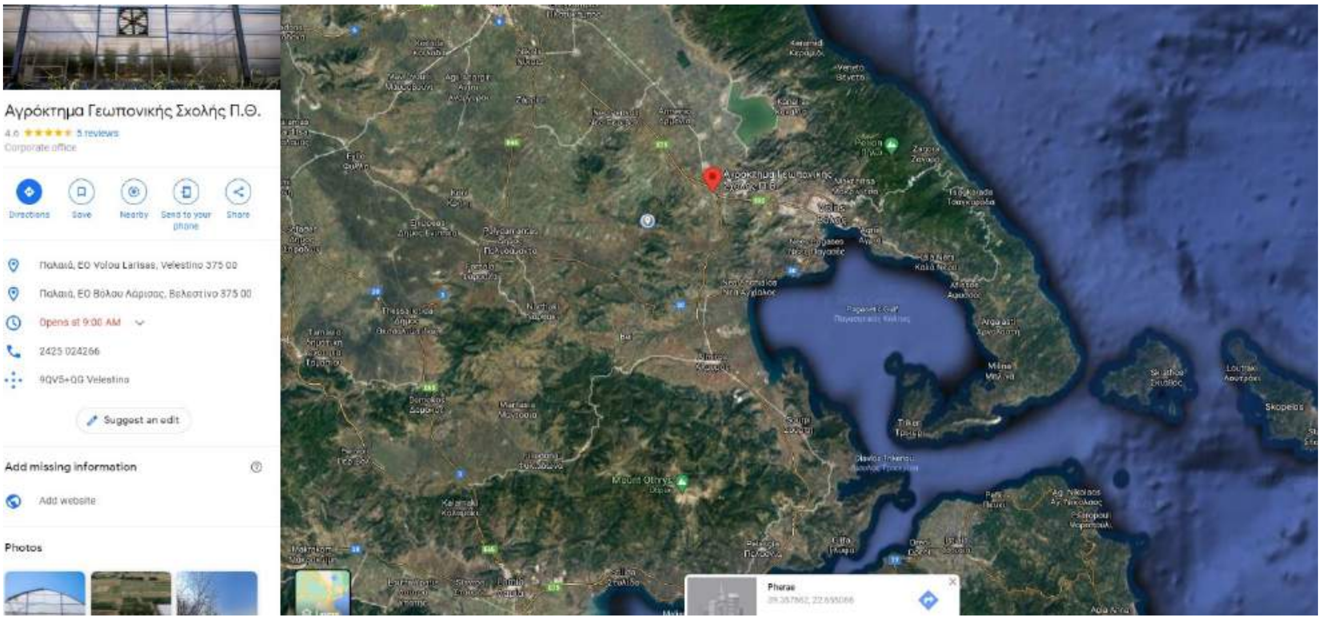

Figure 4. Location of “Agroktima Velestino”

Figure 5. Overview of “Agroktima Velestino”

CLIMATE CONDITIONS (inside and outside the greenhouse)

The mean minimum and mean maximum air temperature of the area is registered in January and July, 3^0C and 32^0C, respectively. Inside the greenhouse, the minimum temperature might reach 12^0C (in January) and the maximum temperature can reach 28^0C (during July).

GREENHOUSE AND PLANT MATERIAL

The greenhouse (Fig. 6) has an area of 1500 m^2 in total and is divided into six indepentently controlled compartments of 250 m^2 covered area each. It is a high-tech gothic type greenhouse, covered by single polyethylene film in the roof and transparent polycarbonate sheets on the side and gable walls.

The current cultivated plant is tomato, cultivar Elpida (Fig. 7), done in one cultivation period which starts between January and April and it ends on January of the following year (total duration: 9-12 months). Plants' density is 3 plants/m^2 while stems density may vary between 3-6 stems /m^2 (that is max 2 stems per plant), depending on the period of the year. However, for the needs of the farming scenario the crop may change to cucumber so that a comparison between the farming scenario 1 could be feasible.

Figure 6. The greenhouse of "Agroktima Velestino"

Figure 7. Tomato plants in the hydroponic system

The greenhouse is equipped with:

a) pipe rail heating system (Fig.8 and Fig.9)
b) natural (roof vents) and forced ventilation system (Fig.10)
c) pad and fan system for cooling (Fig.11)
d) automated thermal screen for energy saving and shading (Fig.12 and Fig.13)
e) crop suspension system (Fig.14)

Figure 8. Heating system (floor pipes)

Figure 9. Heating system

Figure 10. Forced ventilation

Figure 11. Cooling system (wet pads)

Figure 12. Thermal screen

Figure 13. Thermal screen

Figure 14. Crop suspension system

HYDROPONIC SYSTEM

The greenhouse has a hydroponic system with substrate (soilless). The substrate is perlite or rockwool (Fig.15 and 16).

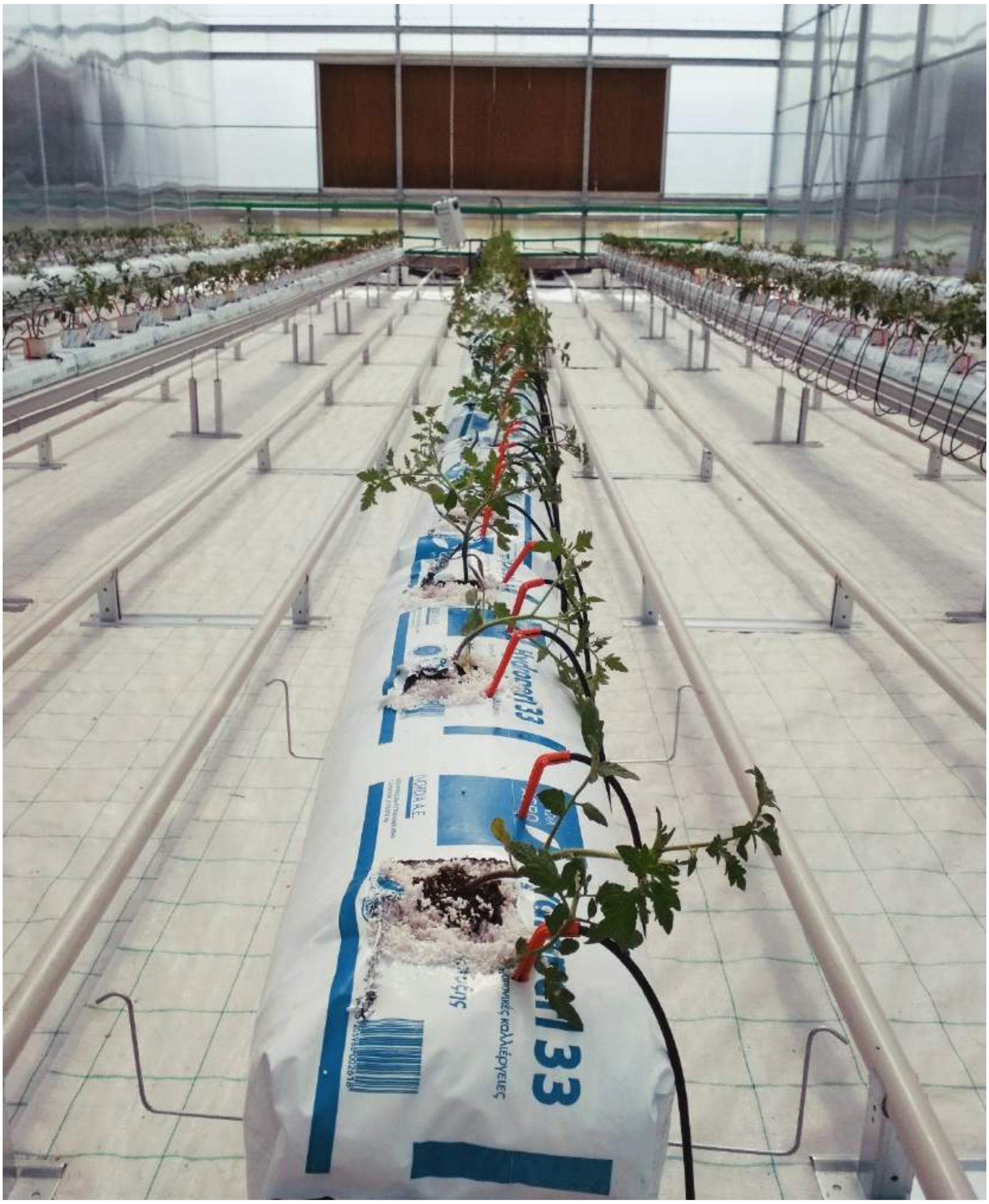

Figure 15. Perlite slabs

Figure 16. Rockwool slabs

IRRIGATION AND FERTILIZATION MANAGEMENT

The hydroponic system could function as an open, closed and semi-closed system. The irrigation system is equipped with drippers every 0.25 m (Fig. 17) and every dripper has a flow rate of 2L/h. The system is controlled by a central computer which is equipped with a DSS that has been developed inhouse (Fig.18, 19 and 20). Irrigation scheduling is based on leachate fraction, solar radiation intensity and the plants growth stage. The irrigation dose and frequency will be based on the predictions for water and fertiliser needs that will be given by the PRECIMED system.

The irrigation dose will be stable during the day while the irrigation frequency will vary according to the climate conditions and crop development.

As for the fertilization, the composition of the nutrient solution is different depending on the stage of cucumber cultivation. Table 3 presents the basic recipe for nutrient solution synthesis at different stages of tomato growth as usually applied by the growers in practice.

The fertilizer mixing system (Figure 22) is composed by the two stock solutions tanks, one acid solution tank, seven injection pumps, the central mixing tank (head unit), the water meter, the UV light, the filter and the EC/pH probes.

Figure 17. Irrigation drippers

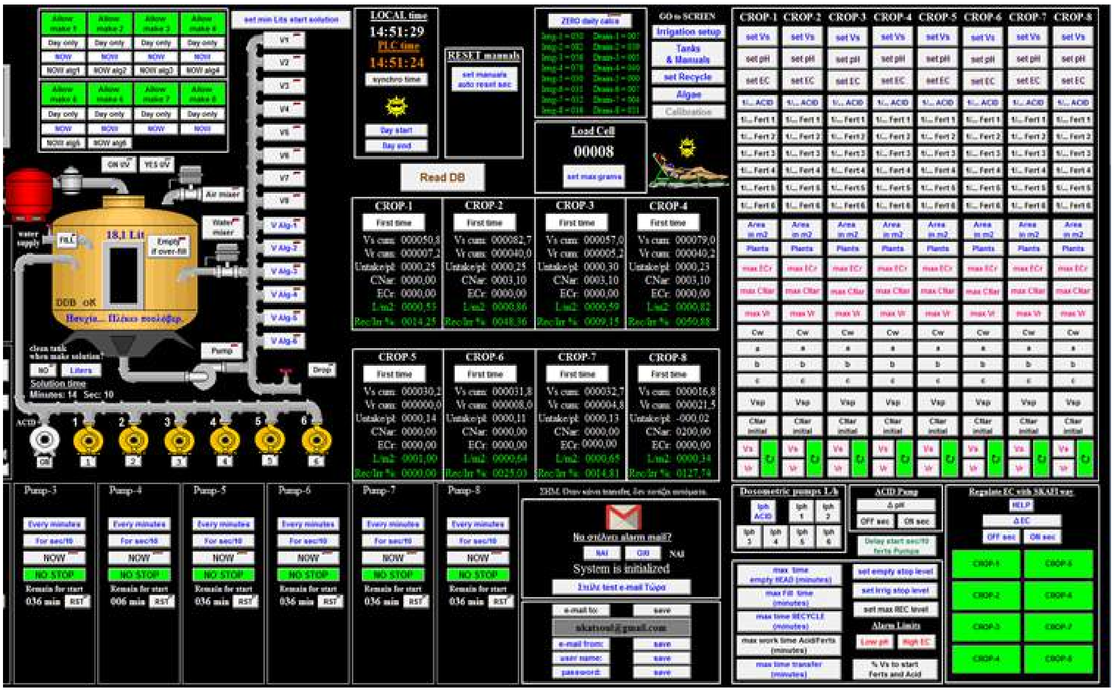

Figure 18. DSS programming software

Figure 19. Recirculation system control

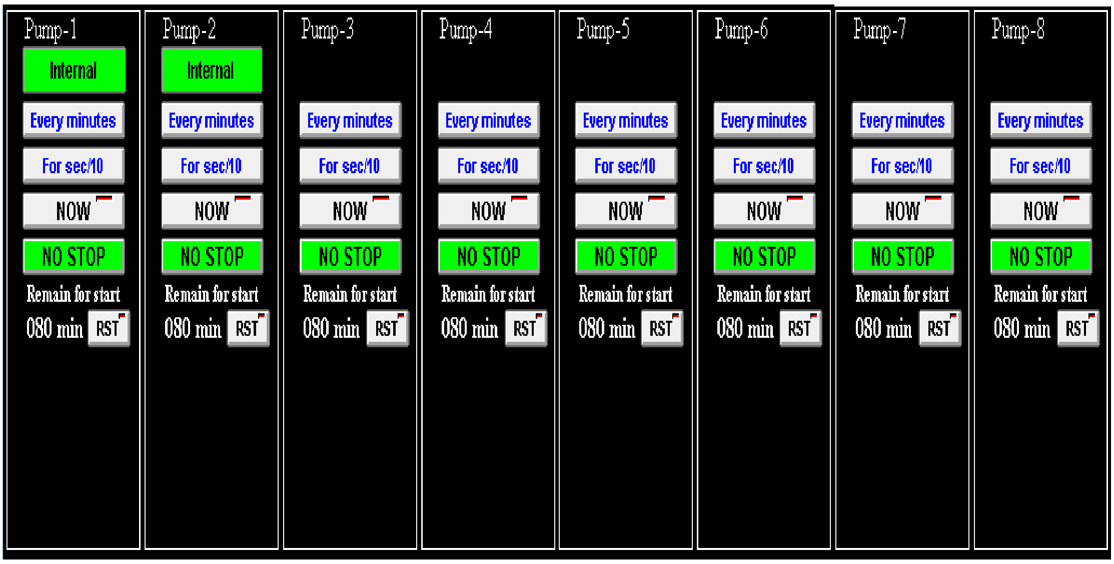

Figure 20. Irrigation scheduling control

Figure 21. Sensors of the PRECIMED system

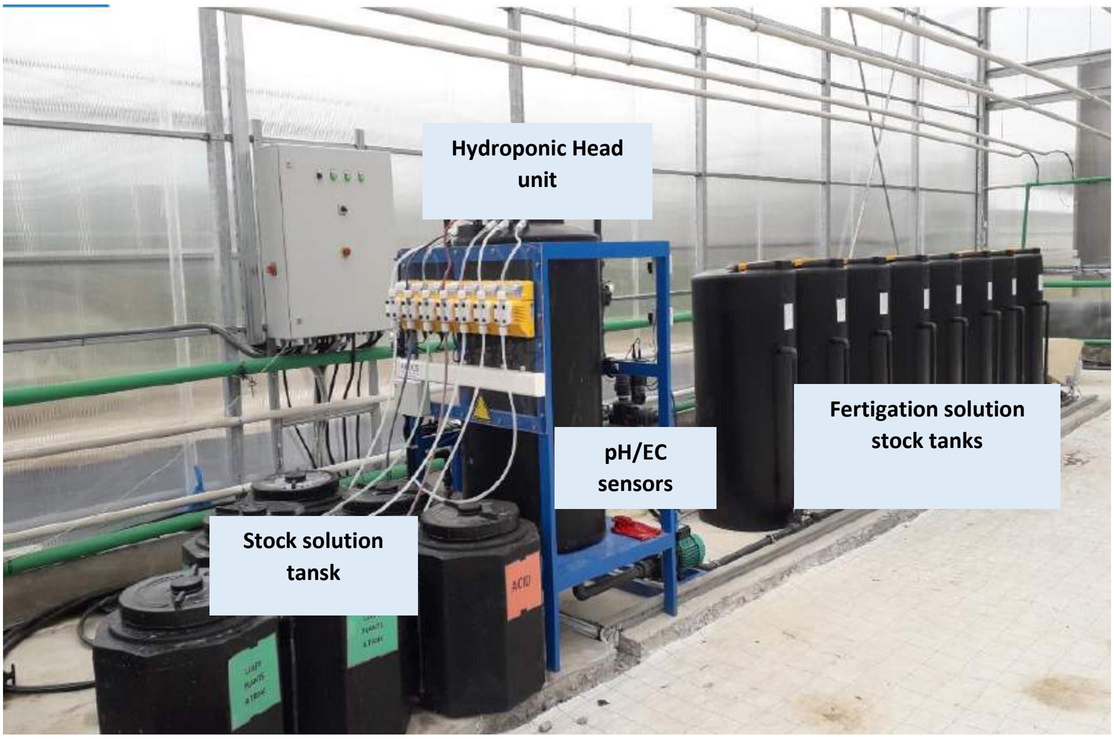

Figure 22. Hydroponic head unit and fertigation solution storage tanks

Table 3. Recommended concentrations of nutrients in the nutrient solution administered in hydroponic tomato cultivation, at different stages of plant growth

		Transplanting – 3rd flower truss	3rd – 5th truss	5th -10th truss	10th truss – end of crop
EC	dS/m	3,1-3,5	3,2-3,5	3,4-3,6	3,5-3,7
pH		5,5-6,5	5,5-6,5	5,5-6,6	5,5-6,8
[K]	mmol/l	7,00	9,00	8,50	8,00
[Ca]	mmol/l	8,00	7,50	8,00	8,75
[Mg]	mmol/l	3,50	3,50	3,75	3,75
[NH4]	mmol/l	<0,8	<0,4	<0,4	<0,4
[Na]	mmol/l	<6,0	<8,0	<9,0	<10,0
[SO4]	mmol/l	4,50	6,00	6,50	7,50
[NO3]	mmol/l	20,0	18,0	18,0	17,0
[H2PO	mmol/l	1,00	1,00	1,00	1,00
[Cl]	mmol/l	<6,0	<8,0	<10,0	<12,0

WATER QUALITY AND AVAILABILITY

Irrigation water has a good quality, with pH= 7 and EC- 0,8 dS/m^{-1}, therefore, there are no salinity issues or other problems derived from irrigation water.

Water resources for irrigation come up from a private drilling, thus water is available on demand. The total irrigation annual requirements amount to about 1400 L/m^2.

HISTORICAL YIELD

The annual tomato production is between 40-50 kg/m^2 of which 77% is classified to Class A while the rest is classified to class B quality category.

PILOT FARM NEEDS ASSESMENT

In the framework of the identification of the requirements of the farms and the farmers, a series of meetings with farmers in Greece was completed. The growers use some indices that help them in the greenhouse microclimate and fertigation management. These indices are:

-Solar radiation entering the greenhouse or at the outside of the greenhouse

-Air vapour pressure deficit and if not available, the greenhouse air temperature and relative humidity

-Volumetric water content of the crop substrate

-pH and EC values of the nutrient solution in the substrate and in the drainage solution

-Ratio of drained to applied nutrient solution

Based on these indices, growers modify on a weekly basis the dose and frequency of the applied nutrient solution. However, they have no tools or basic indices to use in order to modify the composition of the applied nutrient solution and thus they usually apply a standard solution depending on the growth stage of the crop. Nevertheless, they point out that it would be ideal if they could modify the composition of the nutrient solution applied on a weekly or half month basis so that the applied nutrient concentrations are closely related to the fertilisation needs of the crop.

Up to now, the modification of the composition is based on the EC of the drainage solution and is done by changing the EC of the applied nutrient solution rather than changing its composition.

Accordingly, it is pointed out that except of an irrigation scheduling program, the development of a fertigation composition program is necessary.

Finally, growers pointed out that the development of a guide to change the composition of the nutrient solution according to the climate conditions inside the greenhouse and according to the plant growth status would help to better manage the crop production.

Pilot farms in Spain

Farming scenario 1: Pomegranate trees farm

EXPERIMENTAL SITE

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. This is the best-known Spanish cultivar, which produces sweet fruit with soft seeds. The outside color is pink-red and the arils are red.

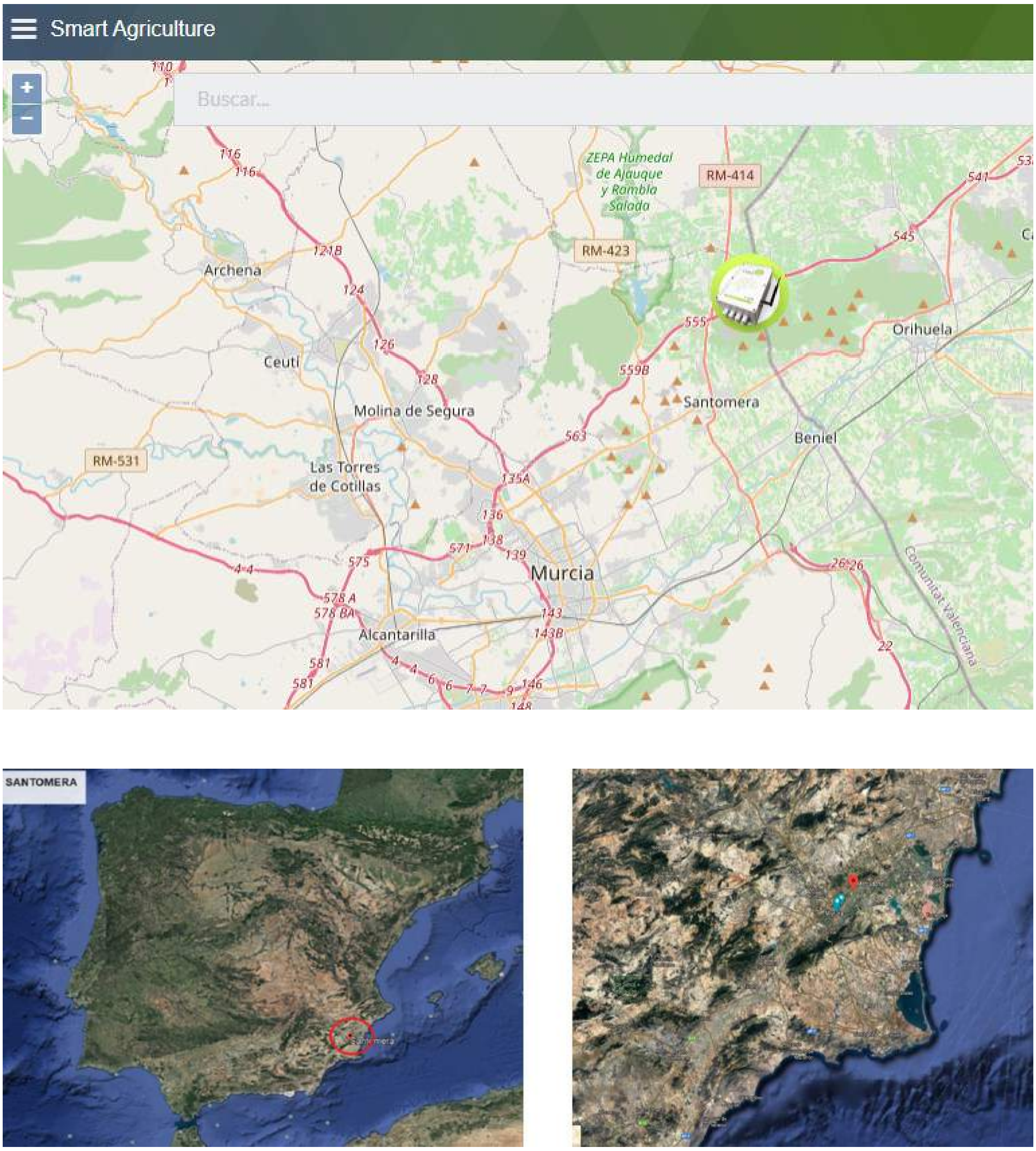

Figure 23. Farm location through PRECIMED platform viewer and satellite images

Trees are spaced following a 3 m x 5 m pattern and the total area cultivated with this variety is 0.8 ha. The pomegranate trees have only one trunk. They are lightly pruned every year and sprouts and suckers are removed as they appear, in order to encourage fruit production.
The sandy clay loam soil of the experimental site (0.93 % organic matter, 0.85 meq/100g available potassium, 51.1 mg/kg kg−1 available phosphorus, 46% lime content and pH of 7.71) is characterized by a high stone content (39% by weight) and a bulk density of 1.37 g/cc. The volumetric soil water content at saturation, field capacity and permanent wilting point is 49, 29 and 18%, respectively. Irrigation water has an electric conductivity of 0.8–1.0 dS/m. Fertilizers are supplied with the irrigation water and pest control practices are those regularly used by local growers, while weeds are not allowed to develop within the orchard.

Figure 24. Overview of the pomegranate pilot farm

CLIMATE CONDITIONS

Meteorological characteristics are proper of the Mediterranean climate. Micrometeorological data (air temperature, solar radiation, air relative humidity, rainfall, and wind speed 2 m above the soil surface) is collected following the World Meteorological Organization's recommendations by an automatic weather station located 0.10m from the orchard at the same CEBAS-CSIC experimental farm (http://www.cebas.csic.es/general_spain/est_meteo.html), which reads the values every 5 min and records the averages every 15min.

Figure 25. Agrometeorological station

Crop reference evapotranspiration (ET0, FAO-56, Penman-Monteith) is calculated hourly. Daily maximum, minimum, and mean air temperatures and daily maximum, minimum and mean relative humidity were calculated, and the daily mean vapor pressure deficit (VPD, kPa) was determined using the following equations:

$$e°(T) = 0.6108 * \exp [(17.27 * T) / (T + 237.3)]$$

$$e_s = (e°Tmax) + (e°Tmin)$$

$$e_a = [(Tmax) * (RHmin/100) + (Tmin) * (RHmax/100)] / 2$$

$$VPD = e_s – e_a$$

Where, e_s is the saturation vapor pressure, e_a is the actual vapor pressure, T is the temperature (ºC) and RH is the relative humidity (%).

IRRIGATION AND FERTILIZATION MANAGEMENT

Irrigation takes place by mean of a drip irrigation system, with one lateral pipe per tree row and six emitters (spaced 50 cm and each delivering 2.2 L h^-) per plant. During the last two years the whole block has been irrigated uniformly, fulfilling the crop water requirements (crop evapotranspiration, ETc), 115% ETc, calculated as ETc = ETo x Kc, where ETo refers to the crop reference evapotranspiration calculated as the Penman-Monteith equation (Allen *et al.*, 1998) and Kc stands for the crop coefficient for each phenological period. However, during the three previous years different works have been done on this experimental farm, to better understand different aspects about water stress on pomegranate trees. This way, different deficit irrigation strategies (DI) were carried out, dividing the complete block into several plots completely randomize with three adjacent tree rows, according to the experimental design of the research. Consequently, total irrigation water amount has been controlled by in-line water meters, as it we will be done again during this trial. At the moment, trees at the farm present a uniform development.

Soil humidity and temperature are registered by the PRECIMED platform in two points of the farm and at different depths (10, 20, 30, 40, 50, 60 cm) through Drill and Drop soil probes (Fig. 26), allowing its monitoring at real time.

Figure 26. Instalation of the Drill and Drope soil probes.

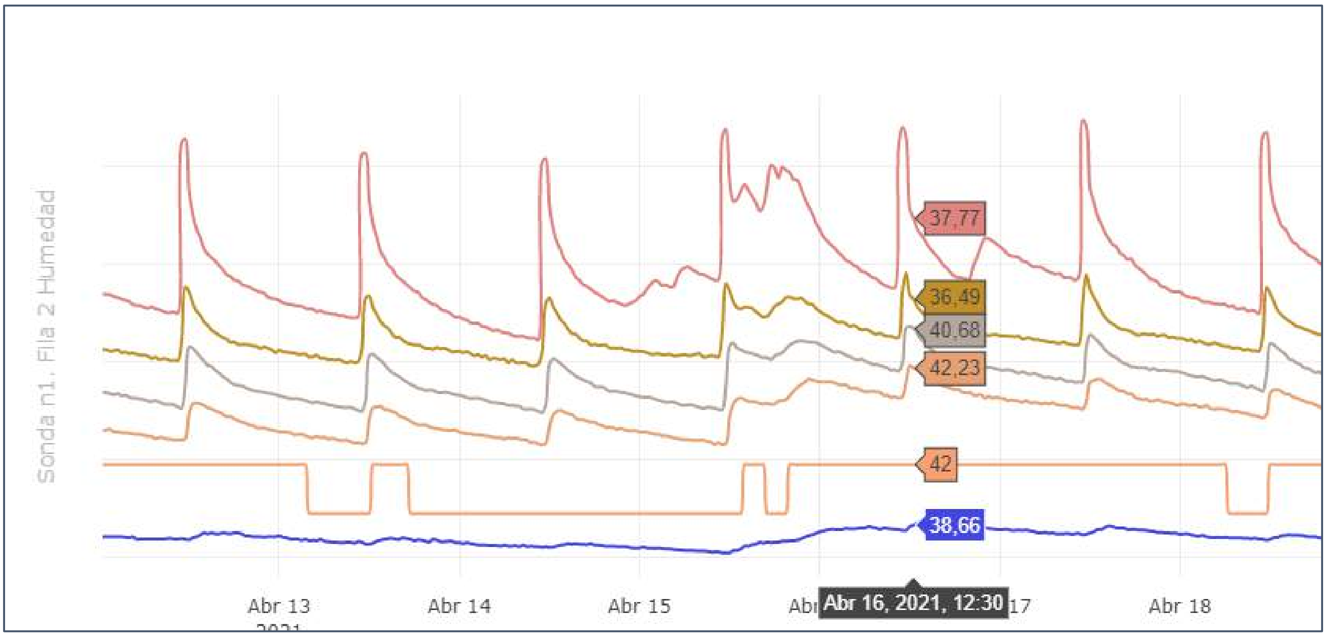

Figure 27. Overview of soil moisture readings at different depths through PRECIMED platform

In addition, 24 fully integrated digital TDR soil moisture sensors (TDR-315H) which register soil moisture at 20 and 40 cm depth and 16 infrared temperature sensors with an angular field of view of 22º (Apogee instruments, Utah, USA, model SI-111), which monitor tree canopy temperature, have being installedat the beginnnng of the 2021 season, in order to better evaluate the effect of the differentt deficit irrigation treatments in the orchard. Both soil moisture and leaf temperature sensors were connected to two dataloggers (model CR1000 with AM16/32 multiplexer, Campbell Scientific Ltd., Logan, USA) and programmed to report means every 30 minutes.

Figure 28. Setting up the different sensor cited above

All these automatic readings, are sinchronized with manual and periodic measurements to monitor different physiological parameters, and improve the knowledge about the relation of soil-plant water status.

Fertilizers are supplied through fertigation, according to the results of the soil and plant analysis made at the beginning of each season. The average dose of the three main nutrients (N, P, K) in the last years has been around 110, 60 and 80 kg ha^{-1} $year^{-1}$, respectively.

PREVIOUS RESULTS

In the context of climate change, the problem of water scarcity for agriculture has been accentuated during the last years. In this sense, Mediterranean countries are increasingly looking for more innovative irrigation approaches, not only to cope with water scarcity and policies involving greater use of water, but also to satisfy the needs of the farmers and the demands of the consumers.

Pomegranate plants cope with water stress developing stress avoidance and stress tolerance mechanisms and they are considered as a drought-resistant crop (Rodríguez *et al*. 2012, Galindo *et al*. 2014a), however when they are produced with commercial purposes, they require regular irrigation along the season, especially in arid or semiarid areas, in order to achieve optimal yields with high quality fruits (Holland *et al.* 2009) and to reduce fruit physiopathies, as fruit cracking and splitting (Galindo *et al.* 2014b, Griñán *et al.* 2019).

In this last respect, deficit irrigation strategies might play an important role for pomegranate production in Mediterranean countries, improving water use efficiency at farm level and complementary reducing nutrient loss from the root zone. According to this matter, in a review done in 2018 by Galindo *et al.*, they highlight three main DI strategies for pomegranate production, among other corps: sustained deficit irrigation (SDI), in which water restrictions are applied following a constant pattern along the season; regulated deficit irrigation (RDI), in which water restrictions applied vary according to the crop phenological stage (critical or non-critical periods); and partial root-zone drying (PRD), which is based on irrigating one part of the of the root zone, leaving the other part to dry until certain extent and then shift the irrigation to the dry side.

One of the major criteria for the commercial quality of pomegranate fruits are fruit size, external color, and shape. Fruit size is mainly affected by crop load and plant water status, which must be controlled to obtain large fruits. In this respect, Cano-Lamadrid *et al*. (2018) suggest that reducing irrigation in a 40% during the flowering and ripening phase, combined with a manual thinning, might increase some organoleptic characteristics of the fruits, as well as their weight and size, although this positive effects were cultivar-dependent. Thus, DI strategies might be used as a field practice to control fruit ripening timing, enhance fruit chemical composition and also improve fruit postharvest performance (Laribi *et al*. 2013).

Galindo *et al.* (2014a) showed that SDI reduces total yield per tree, as well as the number and size of fruits, although some chemical characteristics of the fruits can be directly beneficiated with this strategy. Intrigliolo *et al.* (2013) studied pomegranate response to RDI at different crop cycle stages, highlighting that flowering-fruit set period is not a critical period to implement a RDI strategy, while the linear fruit growth phase, the last part of fruit growth and the ripening phase are critical periods. In agreement with this authors, Martinez-Nicolas *et al.* (2019) also reported as a non-critical period the flowering-fruit set period. But in this occasion, they found that withholding irrigation water during this period, might result in important water saving (19-30%) compared with fully irrigated strategies, increasing the water productivity around 416%. In addition, the marketable yield and the fruit size was maintained and they also make a remark on the reduction of the pruning cost and the fact that fruits presented reddish arils, as a complementary advantage for farmer's crop revenues and consumer's acceptance. Galindo *et al.* (2017) confirmed fruit ripening as a critical period, showing that even short periods of water restrictions at this stage, bring forward the harvest time, saves irrigation water, enhances some bioactive compounds, which can result in an increases of the fruit price without affecting marketable yield and fruit size. Regarding this last aspect, Griñán *et al*. (2018) report an important reduction in the marketable yield, when pomegranate trees were exposed to water stress (irrigation withheld) during fruit growth and ripening phase (DOY 209 to 269), coinciding with the period when evaporative demand is very high and water availiabilty very scarce in the area of the studio, Murcia. On the other hand, Laribi et al. (2013) found slight differences regarding total yield under different DI strategies (see table 1) during a three year experiment, despite the important differences in water application, corroborating the ability of pomegranate trees to withstand drought conditions. In a two years trial, Parzivi *et al.* (2012) recommend PRD at 75% ETc as the best strategy to irrigate pomegranate adult trees, as it increased the yield and the water use efficiency over another DI strategies and full irrigation plots.

Besides some ambiguous results concerning the effects of DI on pomegranate production, it is fair to say, that the effects of water deficit depends not only on the timing but also on the duration and magnitude of the same. Hence, the plant water status during non-critical periods has to be maintained, to avoid negative effects caused by a severe drought that exceeds the tolerance threshold. In this sense, situations as a rapid increase of temperature when low amount of irrigations are applied, can difficult the task of maintaining the plant water status, resulting on yield losses or diminishing fruit quality. This way, the use of plant-based water status indicators might predict crop performance under a given irrigation scheduling regime, since plant water status controls several physiological processes and crop productivity (Ortuño *et al.* 2010). Maximum daily shrinkage (MDS) has been shown as a reliable tool for the development of automated irrigation scheduling in crop trees. Galindo *et al*. (2013) identified MDS as the most suitable plant-based indicator for irrigating scheduling in adult pomegranate trees, emphasizing that the same signal intensity threshold values can be used in different orchards.

Table 8. Overview of the effect of different irrigation strategies on total yield (TY), marketable yield (MY) and water productivity (WP) in cv. Mollar de Elche with a non-exhaustive list of references.

Treatment	TY	MY	WP	References
Full irrigation	29.5	25.4	5.6	Martínez-Nicolas et al. 2019
Irrigation witheld during flowering and fruit set	27	21.9	6.4	
Full irrigation		26	4.8	Cano-Lamadrid et al. 2019
RDI: 60% ETc from fruit setting to harvest		19.7	6	
Full irrigation	42.2	33.8		Griñán et al. 2018
Irrigation withheld during fruit growth and ripening	26.4	17.6		
Full irrigation	21.8		3.9	Intrigliolo et al. 2013
SDI : 50 % ET whole season	21.3		5.9	
RDI 25% ET during flowering and fruit set	24.3		4.9	
RDI 25% ET during fruit growth	20.6		4.6	
RDI during ripening	20.2		4.2	
Full irrigation	43.4			Galindo et al. 2014
RDI: 33% ET from 2nd half of rapid fruit growth to last harvest	32			

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Farming scenario 2: Pear trees farm

EXPERIMENTAL SITE

The plot is part of the Miraflores Irrigation Community in Jumilla, Murcia, in the southeast of Spain (38° 28' 24.495'' N 1° 19' 42.761'' O), (Fig.29). It is a municipality characterized by the absence of water which has been excluded from the water supplies of the Tajo-Segura Aqueduct. Due to the lack of water, water for irrigation is obtained from wells and by concessions of reclaimed water from a treatment plant located in Jumilla.

Miraflores Irrigation Community is composed of nearly 1000 members with a total area dedicated to the irrigation infrastructure of 1515 ha. The main crops, according to the percentage of the total irrigation surface (1329 ha) are: pear (45%), peach (32%), apricot (12%), olive (5%), plum (3%), grapes (2%) and almond (1%).

Figure 29. Plot location

CLIMATE CONDITIONS

Due to the warm influences of Mediterranean climate and the continental influences of Spain's interior, this area has privileged climatic conditions for fruit prodiction. In summary, a high number of hours of sunshine, dry winds from the Northwest, medium-high temperatures and marked contrasts day and night.

CHARACTERISTICS OF THE PLOT

The pear trees, Ercolini variety, are located in a plot of 0.42 ha (Fig. 30), of sandy-loamy soil. They have a planting frame of 4 x 5m, the number of emitters per plant is four, each with a flow rate of 4 l/h. Irrigation water has an electrical conductivity of 1.3 dS/m.

Ercolini is the predominant variety of this crop, due to its excellent adaptation to the climate of the area and the great prestige and acceptance it has achieved in the export market, enjoying one of the three Protected Designations of Origin nationwide of this crop. The specific characteristics of the climate in this region, are ideal for the flowering, fruit setting and subsequent development of pears. During ripening, the high number of hours of sunlight that the fruit receives, give the Jumilla Pear a high content of soluble solids (mainly sugars), being synonymous of flavor and quality.

Figure 30. Pear trees at the pilot farm

PLOT EQUIPMENT:

The plot is equipped with an agrometeorological station, which measures temperature, humidity, radiation, wind, lightning, precipitation and vapor pressure deficit (Fig.31). Moreover, there are soil humidity sensors, installed at different locations of the farm.

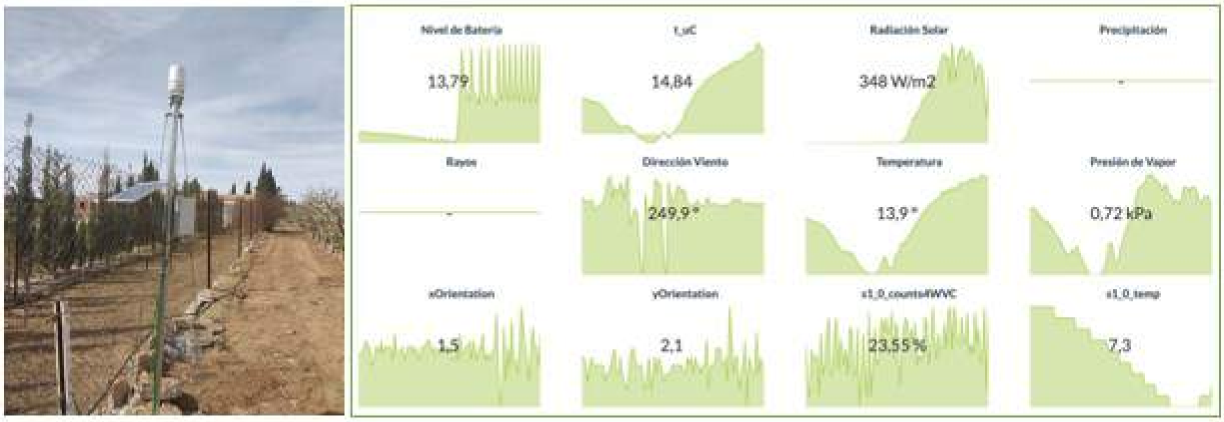

Figure 31. Agroclimatic station and dashboard of different parameters recorded

As part of the Irrigation Community, the farm has benefited of the innovations that the Community has carried out during the last years, as it has being the installation of a photovoltaic plant and the use of a high volume of reclaimed waters from a wastewater treatment plant sited nearby, actions which have had a positive impact regarding the reduction of the energetic cost and the groundwater use.

The Irrigation Community began in 1995, a process of modernization and improvement of infrastructures, in order to keep crops alive and strong. To control the water consumption of each parcel of the partners, a meter was placed on each of them. In order to ensure that the water reached each plot correctly, the water was raised by six pumps to the reservoir, and then it was distributed. To further improve this process, this community began last August the creation of a photovoltaic plant that generates enough electricity to raise the water without using the traditional network system. This has made it possible to reduce the cost of moving the water network and improve the system and make it a much more efficient and sustainable method.

This Community of Irrigators, has more innovations. The water used for all the plantations comes from underground aquifers. The reclaimed water is driven by available flow rates to six interconnected regulation basins. The ponds have modern filling and impulse automatisms that aim to optimize their exploitation and their energy consumption. Both the photovoltaic plant system and the use of wastewater have made it possible to preserve and maintain an element as scarce as hydraulic resources in all fields in the Region of Murcia.

IRRIGATION AND FERTILIZATION MANAGEMENT

Fertigation takes place by mean of a dripping system, since it improves the efficiency of fertilizers and water use. Combining this type of irrigation with humidity sensors, the results might be excellent, not only from an economic point of view, but also environmentally. On the plot, localized dressing fertilization was carried out in strips, under the trees, with combinations of manure and compost. Through fertigation, sulfate of potash and microelements were incorporated. Also, foliar applications of algae were made in pre and post-flowering. The watering doses applied monthly are shown in the following table:

Table 9. Annual irrigation application

Month	*m^3/Ha*
January	0
February	119
March	282
April	489
May	1.020
June	1.332
July	1.097
August	977
September	423
October	0
November	0
December	68

PILOT FARM NEEDS ASSESMENT

At the begining of the project, several meetings took place with representative farmers and other stakeholders of Murcia Region in order to identify the requeriemts of the pilot farms to achieve the project goals. It was concluded that to improve the water use of any farm through a DSS, each pilot needed:

- An agroclimatic station, to monitor, at least, rainy events and crop evapotranspiration.

- Caracterize the soil, trough an initial physico-chemical analysis, describing soil texture, organic matter content, salinity and nutrient content.
- Analyze irrigation water, to check water quality, electrical conductivity and pH.
- Describe the crop coefficient (Kc) for each phenological state of the plant, to apply it according the to the local conditions of the farm.

In addtion, to obtain more robust data which might help to model crop water needs, different soil/plant sensors (already mentioned above) has being installed at the pilot farms. This way, the DSS, as well as the different deficit irrigation strategies applied, will be examinated and validated through different methodologies.

Pilot farms in Algeria

Two farms have been selected in Algeria, distancing themselves about 250 km and representing different agroclimatic zones. Both farms have different crops and objectives, as it is described below.

Figure 32. Location of both "pilot farms"

Farming scenario 1

This farm is specialized in the cultivation of fruit trees, mainly citrus, apple and peach trees, although it also has a vineyard.

EXPERIMENTAL SITE

The farm is located in Mitidja plain, in Sidi Moussa, Algiers in northern-central Algeria, 36° 35' 52" N, 3° 05' 37" E, at an elevation of 54 m. The farm is characterized by rich, deep and heavy soils, with a high clay content. Soil analysis revealed the existence of 3 horizons of clay-silty texture with levels of clay increasing in depth. With the heavy rains in winter, the soil surface could be affected by waterlogging. The Total Available Water (TAW) is around 140 mm/m. The farm has a vocation of fruit arboriculture covering an area of 22.1 ha of which 10.6 ha are planted with citrus, 1.77 ha of apple trees, 1,98 ha of vine and 4,29 ha of peach trees. Plant densities are:

- Citrus: spaced following a 6 x 6 m and 5x5m pattern for the old plantation, and a 3 x 6 m for the new ones.
- Apple: 2 x 3.5 m.
- Table vine: 2 x 3 m.
- Peach trees: 3 x 4 m

The citrus plantation has a larger planting pattern, due to a common practice in those years, which was to irrigate by surface (flooding irrigation). Since year 2000, the country launched a new program based on the agricultural intensification, which includes the introduction of improved irrigation systems and good agricultural practices, as a better fertilizer management, new high yielding varieties, plant protection, etc. This fact explains the larger densities observed in the new plantations.

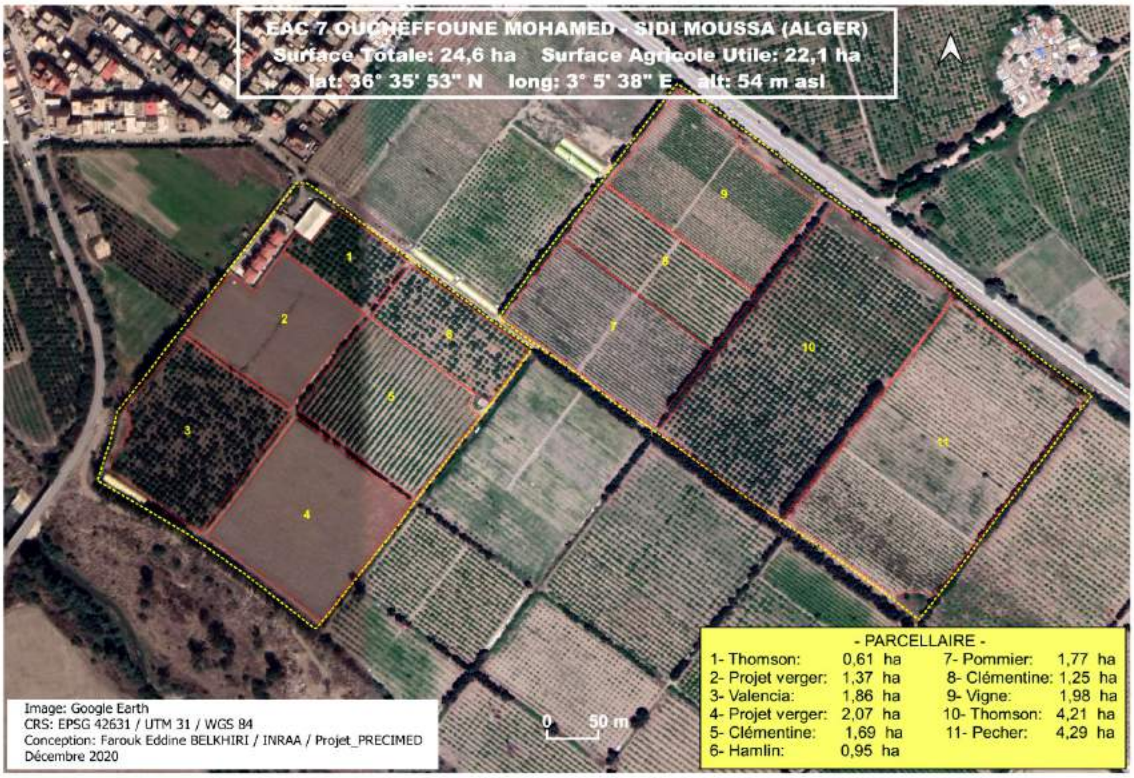

Figure 33. Mapping of plots distribution at the farm EAC 7 at Sidi Moussa, Algiers.

CLIMATE CONDITIONS

This region is characterized by Mediterranean climate, with mild and rainy winters and hot and dry summers. Ombrothermic diagram of Bagnouls-Gaussen locates the dry season between May and September, period in which summer crops demand a bigger water supply, due to a higher evapotranspiration (Fig. 34).

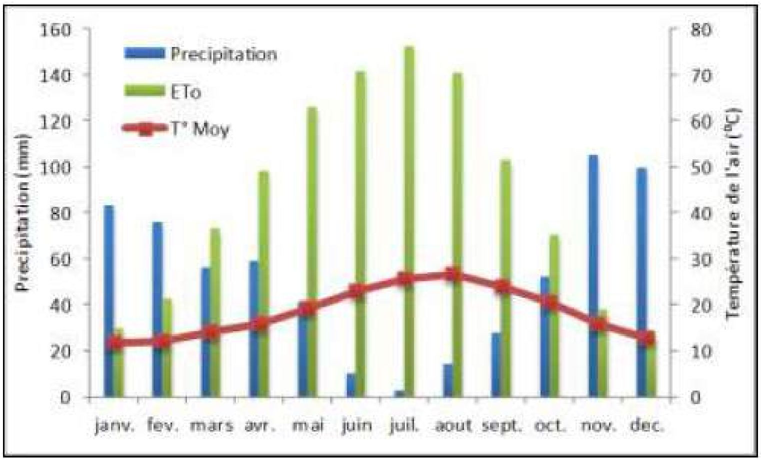

Figure 34: Average precipitation, evapotranspiration and air temperature recorded at INRAA Station of Baraki (Algiers), period 1990 – 2014.

The local measurements over 25 years (1990-2014), show an average annual precipitation of 628 mm, which a high proportion (76%) is recorded between November and April. This amount meets largely, the water requirements of winter crops, thus extra irrigation supply it is not needed for open field crops at this time. Average annual temperature is 18.4°C, oscillating between 6.6°C in January and 31.8°C (in August).

The accumulated evapotranspiration is 1042 mm per year, with a daily average of 2.8 mm and with an increasing trend from January (1 mm / day) to August (5 mm / day). The annual average of water deficit is about 414 mm, being the largest part, recorded between June and September.

An automatic weather station (AWS) iMetos 3.3 model IMT 280, is installed inside the orange orchard which collects meteorological data. The variables measured are: air temperature (T), relative humidity (RH), solar radiation (Rs), wind speed (WS) 2 m above soil level, rainfall (P), dew point (DP), vapour pressure deficit (VPD) and daily evapotransporation (ET).computed by the FAO-Penman-Monteith method. The recorded variables can be downloaded from the website (https://ng.fieldclimate.com/). The climatic data can be recorded by steps of 10, 15, 20, 30, 60 and 120minutes. Currently, it is recording every hour.

Fig 35: Imetos weather station installed at the pilot farm

IRRIGATION AND FERTILIZERS MANAGEMENT

The farm is equipped with a drip irrigation system. Drippers are spaced 1 meter to each other and have a flow rate of 8 L h^{-}. Citrus trees have two lateral pipes per tree, resulting four drippers per tree in the young plantation and six dippers per tree in the old one, due to the structure of roots (according to the farmer). Apple and peach trees have one lateral pipe per tree row and two emitters per tree.

Irrigation scheduling is based on farmer experience and visual observations of the plant and soil in despite of the availability of climatic data. This is the common method used by farmers. It is a quick and easy method because investment in equipment and technical support is not needed. On the other hand this is not an accurate method, and in some occasions, it can cause an excessive water stress suffered by the trees with negative consequences, affecting the yield and crop quality.

Figure 36. Overview of the irrigation system at the farm

The irrigation is more frequent during the hot and dry periods of the year. The irrigation season starts from mid-April to the end of July for apple and peach trees and continue until December for citrus.

The irrigation frequency is every 2 days and the duration of irrigation event is about 2 hours during the beginning of the irrigation season (mid-April / mid-May) and it reaches 4 hours from mid-May onwards. An estimated irrigation volume is shown in Table 10:

Table 10: Estimation of irrigation doses used under fruit tree cultivation (mm)

Crop	Old citrus trees	Young citrus trees	Apple trees	Peach trees
Beginning of irrigation season	35.6	23.7	26.67	26.67
Hot period of irrigation season	71	47.4	53.33	53.33

These calculations were performed as follow:

$$V = Q * t$$

$$= A * IB$$

Where V (m^3) is the volume of water delivered, Q (m^3/s) is the flow, A (m^2) is the estimated area by tree, and IB (mm) is the irrigation dose, assuming that a citrus tree covers 9 m^2 and peach and apple trees covers 4 m^2 and the wetted area is estimated at 30%.

A humidity sensor (Drill and Drop soil probe) is planned to be installed at farm level for the monitoring at real time of soil water content. The Drill and Drop probe is not received so far. If the reception of the sensor takes a long time, it will be replaced by a Diviner 2000.

Water resources for irrigation come up from 2 private wells, within a depth of 160 m and equipped with an electrical pomp of 25 cv and a flow of 30 m^3 per hour. The wells are connected with the irrigation system, in despite of the existence of a basin with a capacity of 100 m3. Thus, water is available on demand. The total annual irrigation requirements are around 12,000 m^3/ha.

Concerning the fertilization, the main mineral fertilizers applied are N, P2O5 and K2O. Application rates depends on the fruit development stage of the different crops. . Table 11 presents the fertilizers rates recommended for the mentioned crops and Table 12 shows the recommended timing for its application.

Table 11: Recommendations of fertilizers for fruit trees cultivations

Crop	N	P2O5	K2O
	(U.F. ha^{-1})		
Apple	160 - 200	80 - 120	120 - 160
Peach	140 - 180	60 – 80	100 - 120
Citrus	250 - 300	100 - 120	100 - 160
Vine	140	80	100

Table 12: Timing fertilizers recommendations (U.F. ha^{-1})

Months	October	February	April	May	June	July	August
Apple	80 - 120 (P) 120 - 160 (K)	30 – 40(N)		96 - 120 (N)		- 30 - 40 (N)	
Peach	60 – 80 (P) 100 – 120 (K)	30 - 35(N)		80 - 110 (N)		- 30 - 35 (N)	
Citrus	100 – 120 (P) 100 – 160 (K)	70 (N)			40 (N)		40 (N)
Vine	80 (P) 100 (K)	70 (N)	70 (N)				

The activities under the PRECIMED project at this pilot farm, will be foccussed on citrus, as it is one of the crops more cultivated in Algeria, (occupying the third place after olive and date plam), and the need of improving water and fertilizer use efficiency is of a great interest for citrus farmers. Within this context, different deficit irrigation strategies will be applied to find the best approach for the region.

Farming scenario 2.1

Potato seed improvement and production laboratory (Tiaret, Sebaine, Algeria)

EXPERIMENTAL SITE

The Potato seed improvement and production laboratory is located in Tiaret region, Sebaine in Western Algeria (35° 27' 41'' N, 1° 36′ 10.22′′ E) and it is at an elevation of 908 m above sea level.

Figure 36: INRAA Tiaret Station

CLIMATE CONDITIONS

The Sebain region has an agricultural and agro-pastoral vocation. It is located at the high plains of the Serssou plateau specialized in cereals production and livestock. The climate is semi-arid with cool to very cool winters and very hot and dry summers with an average annual precipitation of 350 and 500 mm.

An agrometeorological weather station type "Imetos" was installed at INRAA laboratory distant from pilot farm about 3 km.

The potato seed improvement and production laboratory includes, several potato seed production plots (for multiplication purposes) and two multi-chapel glass greenhouses with hydroponic systems.

The first glass greenhouse, has an area of 340 m^2, and its capacity allows to grow between 2000 to 3000 vitro plants, with a production capacity of 60,000 mini potato tubers (seed of category G0), (Fig. 36). Climatic conditions (temperature, humidity and light) are controlled, as the greenhouse it is equipped with an air-cooling system, a heating system and a shading system. Currently, this system needs to be reviewed for a better working condition.

In addition, the greenhouses are equipped with an automatic fertigation station. However, the preparation of the nutrient solutions is made manually, as the automatic system for the preparation of the nutrient solution is not working correctly and it needs to be fixed.

The hydroponic system used in this greenhouse is the technique related to "NFT" - Nutriment Films Technique", for the distribution of the nutrient solutions (Fig 37). The solution is distributed on the crop tables in the form of a water slide of 0.5 to 1 cm of thickness.

Figure 37: Hydroponic system for the production of potato seeds

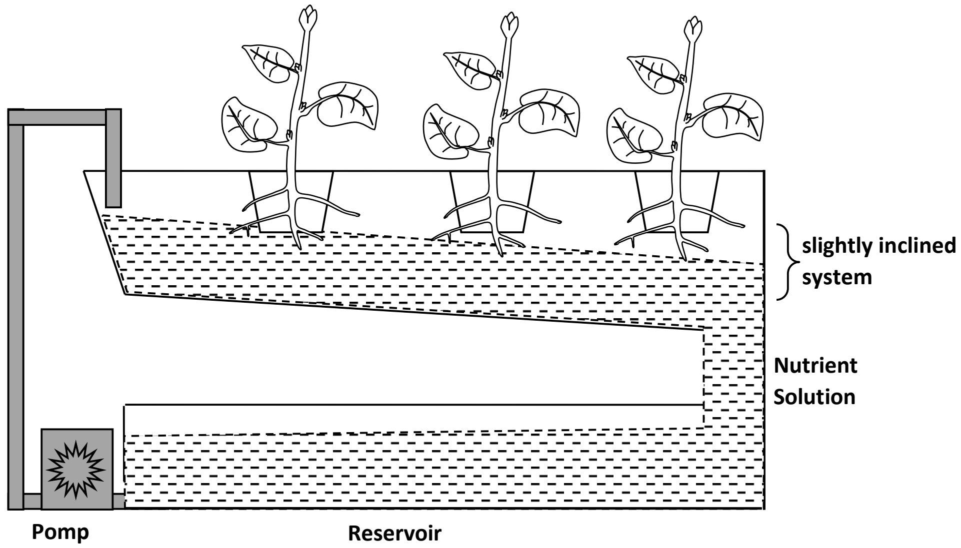

Figure 38. Technique of NFT hydroponic system

The hydroponic nutrient solution is distributed in small channels by mean of a pump located in the reservoir. The solution is continuously charged with oxygen by passing over the surface of the liquid film and the runoff irrigates the plant roots. The system is slightly inclined, so the solution reaches the reservoir after irrigate the plants. It is a closed system, therefore evaporation is limited and consequently there is an important water saving. The solution is absorbed by the plants, and the volume and the concentration of nutrients are continuously readjusted depending on age of the plant.

The second multi chapel greenhouse has a soilless hydroponic system. The substrate in this case, is the potting soil bought locally. This multi-chapel glass greenhouse has an area of 120 m², with a capacity of 1000 to 1500 vitro plants and a production capacity of 6000 to 8000 mini potato tubers (seed category G0), (Fig. 39).

Figure 39: Hydroponic system with substrate (potato seedlings)

This growing system on substrate requires drippers or capillaries, as well as a distribution pipe and a pump. The hydroponic nutrient solution is distributed to the plants by intermittent irrigation on the upper surface and drop down by gravity; at least one dripper is used per plant. The containers include holes in the bottom to allow water drainage.

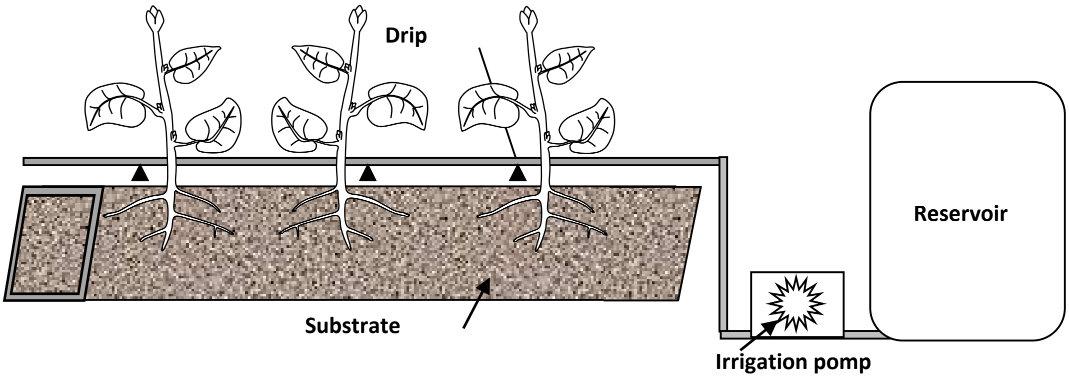

Figure 40: Drip system used in the second greenhouse

This system is one of the most widely used today. It does not recycle the nutrient solution, which is not a very environmentally friendly technique, given the possible contamination of the soil by the drainage of the nutrient solution. Moreover, it is not very efficient from an economical point of view, given a large amount of water used for the irrigation.

Regarding to the fertilization of the first greenhouse, the composition of the nutrient solution is presented in table 13. The choice of the appropriate formulation and the calculation of the salt concentration is made taking into account the chemical composition of the water used for irrigation.

Table 13: Mineral compositions of nutrient solutions used in the greenhouses

	Constituents		
Macroelements	**Tank A**	**mg/L**	**g/400L**
	KNO_3	229	92
	NH_4NO_3	76	30
	$5[Ca(NO_3)_2\ 2HO_2]\ OH_4NO_3$	65	26
	Fe-EDTA	23	3,2
	Tank B	**mg/L**	**g/400L**
	KNO_3	150	60
	$NH_4H_2PO_4$	80	32
	$MgSO_4–7H_2O$	160	64
Microelements	**Tank C**	**mg/L**	**g/400L**
	$MnSO_4–H_2O$ *or* $(MnSO_4–4H_2O)$	1,54 (2,02)	0,62 (0,81)
	H_3BO_3 *or* $(Na_2B_4O_4–4H_2O)$	2,86 (4,42)	1,14 (1,77)
	$ZnSO_4–4H_2O$ *or* $(ZnSO_4–7H_2O)$	0,18 (0,22)	0,07 (0,09)
	$CuSO_4–5H_2O$	0,08	0,03
	$NH_4MO_7O_{24}–4H_2O$ *or* $(Na_2MoO_4–2H_2O)$	0,02 (0,026)	0,01 (0,01)

Plants in the second greenhouse grow in rich potting soil, so no nutritive solution is added to the irrigation water.

Water quality has a basic tendency (pH 7.59), a low electrical conductivity (1.11 dS m^{-1}) and a high concentration of NO3 (174g/l), probably due to the excessive use of fertilizers and the consequent leaching to the subsoil. Water is available on demand, as it comes up from a private drilling.

Table 14: Chemical characteristics of water used under hydroponic systems

Parameters	TDS	Salinity	CE	PO4	NH4	NO3	Ntotal	PH	Ptotal	T°c
Units	mg/l		ds/m^{-1}	mg/l	mg/l	mg/l	mg/l		mg/l	°c
Concentrations	0.59	0.51	1.11	0.15	0.09	174	180	7.59	0.12	19

Requirements of the "seed improvement and production laboratory"

This crop system is not developed at farmers level. So, the requirements of the laboratory come from the point of view of the technical staff. The needs can be summarized as follow:

- The first requirement is related to the control of the microclimatic conditions, closely associated to the equipment in the glass greenhouses including air-cooling system, a heating system, a shading system and the roof openings. These systems must to be fixed and maintained for a better effectiveness.

- Regarding irrigation, the technical staff pointed out that the parameters to be controlled are the electrical conductivity (EC), the pH of the nutrient solution and the nutrient requirements of potato per phenological stage.
- Regarding the substrate, the potting soil water content and the EC are the parameters more relevant to monitor. Others parameters as temperature of plant leaves, leaf wetness, plant transpiration and root temperature are also very important to monitor water and thermal stresses, as well as the development of diseases.

Farming scenario 2.2

Agricultural explotation of vegetables (tomato, potato, green beam) and cereals.

EXPERIMENTAL SITE

The agricultural exploitation is located at 5km distance from *Potato seeds improvement and production laboratory* of Sebaine. The farm has 10 ha, where vegetable production is conducted under irrigation and cereals grow under rainfed conditions.

During the three last years, the main crops practiced were:

- Year 2020 : cereals(6 ha)
  Tomato (5.5 ha) (rented land)
- Year 2019 : Potato (3.5ha)
  Tomato (1.5 ha)
  Green bean (1 ha)
- Year 2018: Potato (3.5 ha)
  Green bean (1 ha)

Under PRECIMED project, activities will be focused in potato cultivation. In fact, in Algeria, the potato sector has a considerable economic weight and it iss considered as a strategic crop in the agricultural programme. The production of potatoes has quadrupled in the past ten years and currently, it reaches 5 million tons per year. Therefore,ptato plays an important role in national food security.

IRRIGATION AND FERTILIZATION MANAGEMENT

The irrigation systems used is sprinkler irrigation. The irrigation season starts from April to December. The irrigation scheduling, as for the pilot farm located at Sidi Moussa, Algiers, it is based on farmer experience and visual observations of the plant and soil. Potato cultivation has two seasonal productions: regular and late season.

Usually, the planting date for seasonal potatoes is April and the harvest occurs in July. The late season starts in September (planting) and the harvest is in December.

A humidity sensor is installed at farm level for the monitoring of soil water content and, consequently, a better control of irrigation.

Regarding fertilization, the main fertilizer used is dry NPK fertilizer 15/15/15. The application rates used are:

Potato : 13 q ha^{-1} equivalent (in kg of N P K ha^{-1}) to 195 / 195 / 195.

These fertilizer rate for potato seems to be very high according of some fertilizers experiments implemented in the site, where better yields and better nitrogen use efficiency were obtained, using a rate of 120 kg ha^{-1}.

Table 15: Recommendations of fertilizers

Crop	N	P2O5	K2O
	(U. ha^{-1})		
Potato	- 80 à 100	100 - 120	200 - 240
	1,5 q of urea 46%		2qx of K2SO4 48%

Water resources for irrigation come up from private drilling connected to a basin for the storage of water, thus water is available on demand. Irrigation water has a pH of 7.59 and EC of 1.11 dS-m-1. The drilling and the basin are equipped with three electrical pumps of respectively 7.5, 6 and 15 cv. To reduce the cost of energy, the farmer plan to use a solar pumping.

Equipement Installed in field

- An Imetos weather station (need to be fixed);
- O1 Diviner 2000. It will be completed by the installation of Drill an Drop probe (This last sensor is not received so far).

Field activities:

- Irrigation scheduling of potato using Diviner 2000;
- Application of three irrigation strategies for potato production.

PILOT FARM 2.1 AND 2.2 NEED ASSESSMENT

A meeting was done with the farmers of both farms in order to assess the requerimets of each farm. They were identified as follow:

- Need to install an agroclimatic station in each pilot farm for the monitoring of climate conditions allowing the precise irrigation scheduling and the monitoring of diseases and pest attacks.
- Need to install some devices for the monitoring of soil water content to control soil water status and, consequently, the defining of precise irrigation scheduling.

- Need of technical support for irrigation scheduling, monitoring and treatment of diseases and pest attacks.

Parameters, as soil water content, total available water, hydraulic conductivity, soil texture, etc. need to be evaluated in both pilot farms, in order to develop an appropiated irrigation program.

A need for the improvement on the fertilizer application was also exposed during the meetings, regarding application rates and timing. Although, the recommendations for the use of fertilizers exists at national level, an effort needs to be made to disseminate good agricultural practices. For a better fertilization program, it is important to perform a soil analysis at the beginning of each agricultural season and then develop and adopt an appropriated fertilization plan for each crop/farm.

Due to the agricultural development and its intensification, policy makers deliver irrigation water with a very low cost, not to say free. Thus, to improve WUE, it is necessary to install on the irrigation stations the adequate equipment to measure water consumption, from the source until the plot.

Pilot farms in Tunisia

Farming scenario 1: Olive trees farm

EXPERIMENTAL SITE

The Farm is located at Sfax - Tunisia (34°31'24.1"N 9°43'45.3"E - 34.523355, 9.729251). The farm cultivates almonds, olives, peaches and nectarines.

Figure 41: Location of the farm

Figure 42: Olive pilot farm

CLIMATE CONDITIONS

As located in an arid region, well known by the lack of rain and a high variation of temperature (day/night), the farm maintains production under difficult climatic conditions characterized by hot summers (exceeding 45 °C) and a relatively cold winter reaching 1 °C. Considering these conditions (climate warning or fluctuations in temperature reaching 45°C), there is a significant risk on the crop production/performance, as well as on the physiological behavior of the plants, which might be also damaged.

IRRIGATION AND FERTILIZATION MANAGEMENT

The farm has a classical drip irrigation system. Olive trees are irrigated at least twice a week, although irrigation is performed every day, as the farm is divided in 24 different sectors which are operated manually by a worker. A sector takes an hour to be irrigated. The irrigation system characteristics are listed below:

- Sounding of 70m, flow at the outlet 3 L / S.
- Energy: Electricity company + Photovoltaic installation for pumping water from the sounding (Fig. 42).
- Pumping Motor: 3 HP submersible pump
- Centrifuge pump for watering: 3 HP
- Basin to accumulate water from the survey: 100 cubic meters
- Drip irrigation: 2 drippers per olive tree each pouring 8 l / h (16 l / h in total) (Fig. 42).

Figure 43: Sounding and irrigation pipes

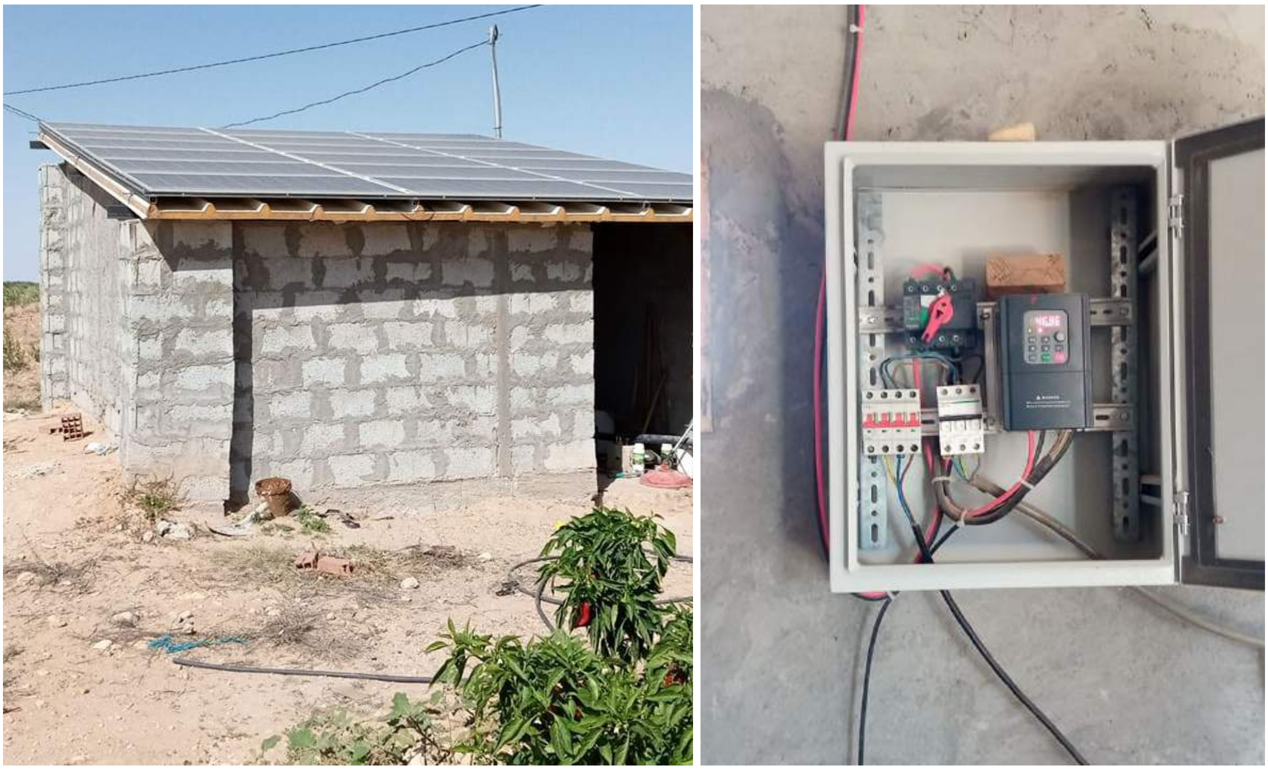

Figure 44: Energy system at the farm

The following table shows an irrigation water analysis made at the farm

Table 16: Water analysis

Analysis	Results	Guide standards
pH	-	6.5 to 8.5
Turbidity	1.5	3 N.T.U
Conductivity	4130	>0.3 and <2.5 dS/cm
Dry residue	-	>200 and < 2000 mg/L
Total hardness	39.8	12mEq/L
Magnesian hardness	124.7	100mg/L
Calcium hardness	592	200mg/L
Nitrates (NO_3)	0	0.2mg/l long term exposure 0.3 mg/l short term exposure
Sulfate (SO_4)	1106	500 mg
T.A complet (TAC)	1.7 mg/l	-
Chlorides	397.6	500 mg/l
Ammonia (NH_4)	0	0.1 mg/l