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Optimizing irrigation for key fruit crops in the Algarve: a contribution to climate change adaptation

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Naoussa (Greece), 17 June, 2025

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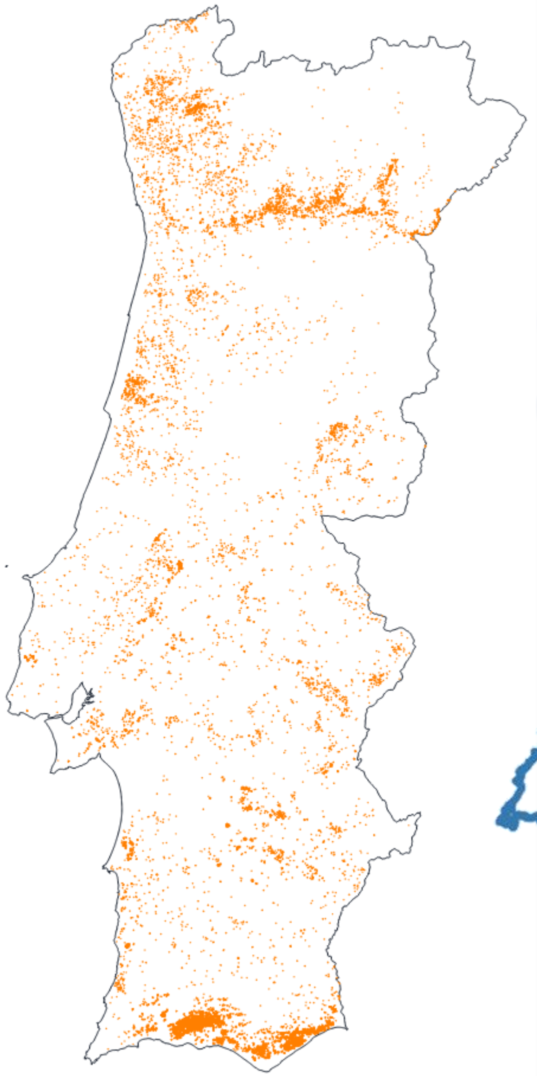

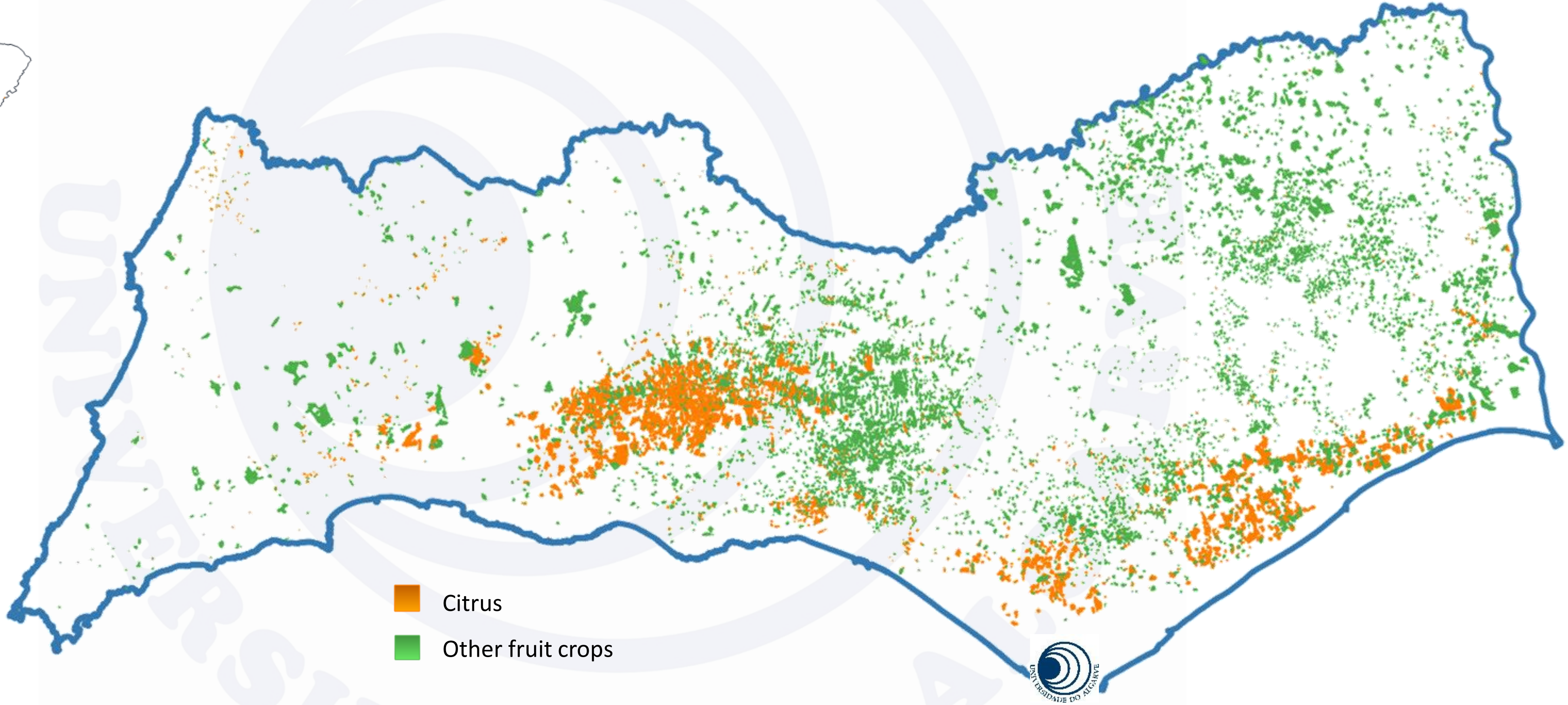

Source: IFAP, adapted by Tomás Magalhães

Importance of the different crop groups in the Algarve (2014-2023)

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Main agricultural crops	Area (ha)	Production (t)
Cereals for grain	2 397	4 558
Main dried legumes	24	16
Potato	319	7 238
Main crops for industry	0	0
Horticultural cultures	?	?
Main forage crops	1 799	33 088
Main fresh fruits (other than citrus)	**3 199**	**12 162**
Berries (Raspberries and others)	**271**	**4 802**
Main subtropical fruits (mainly, avocado)	**2 500**	**31 794**
Citrus	**15 507**	**323 658**
Main nuts	6 081	1 037
Vineyards	1 527	5 142
Olive trees	9 143	4 442

Dodos do INE

Precipitation and temperature

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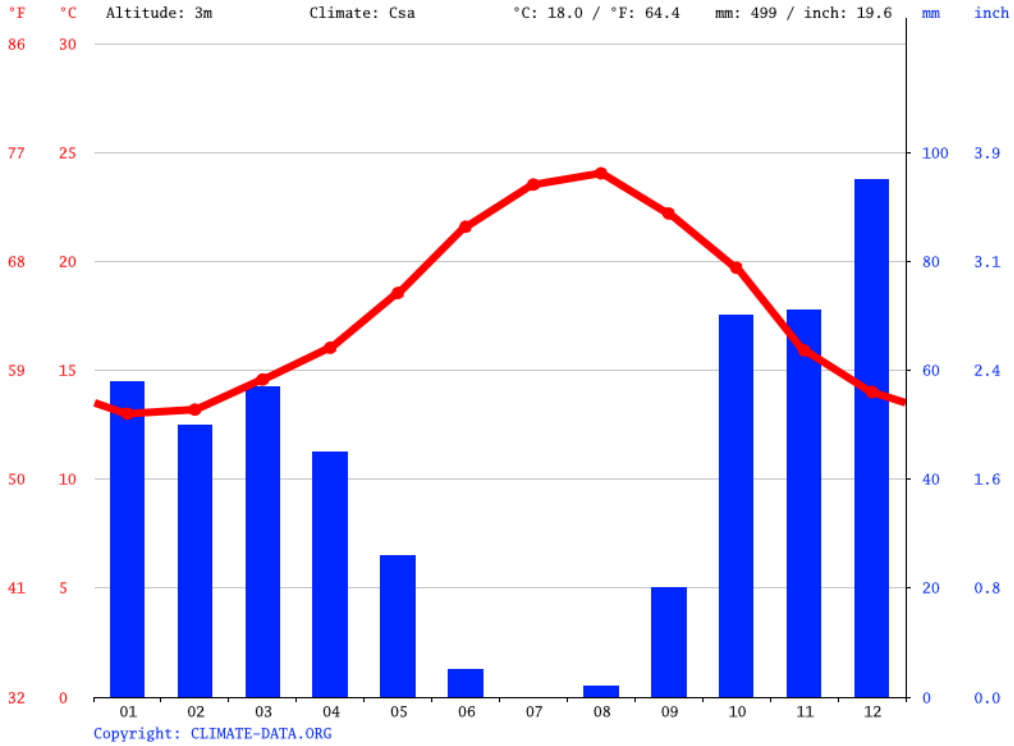
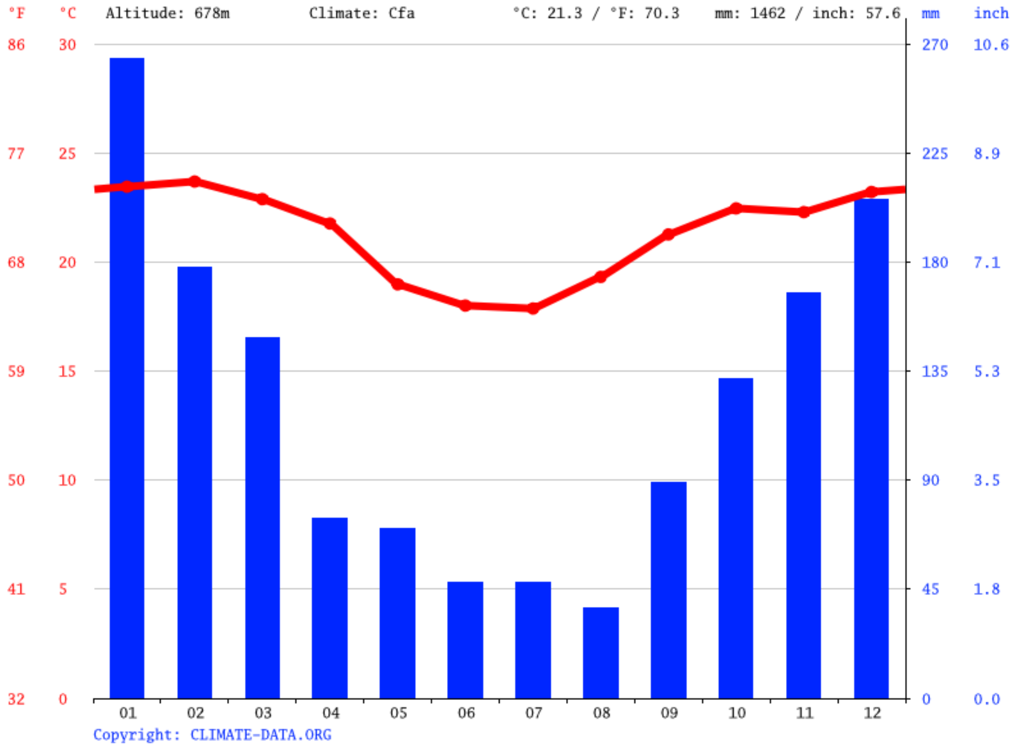
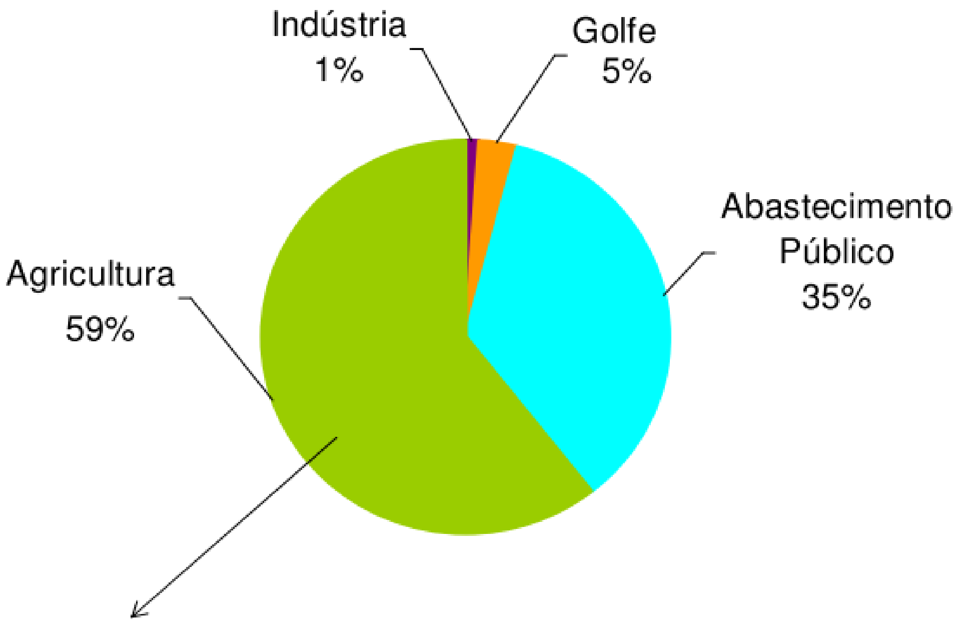
Faro – Portugal



Campinas-Brasil



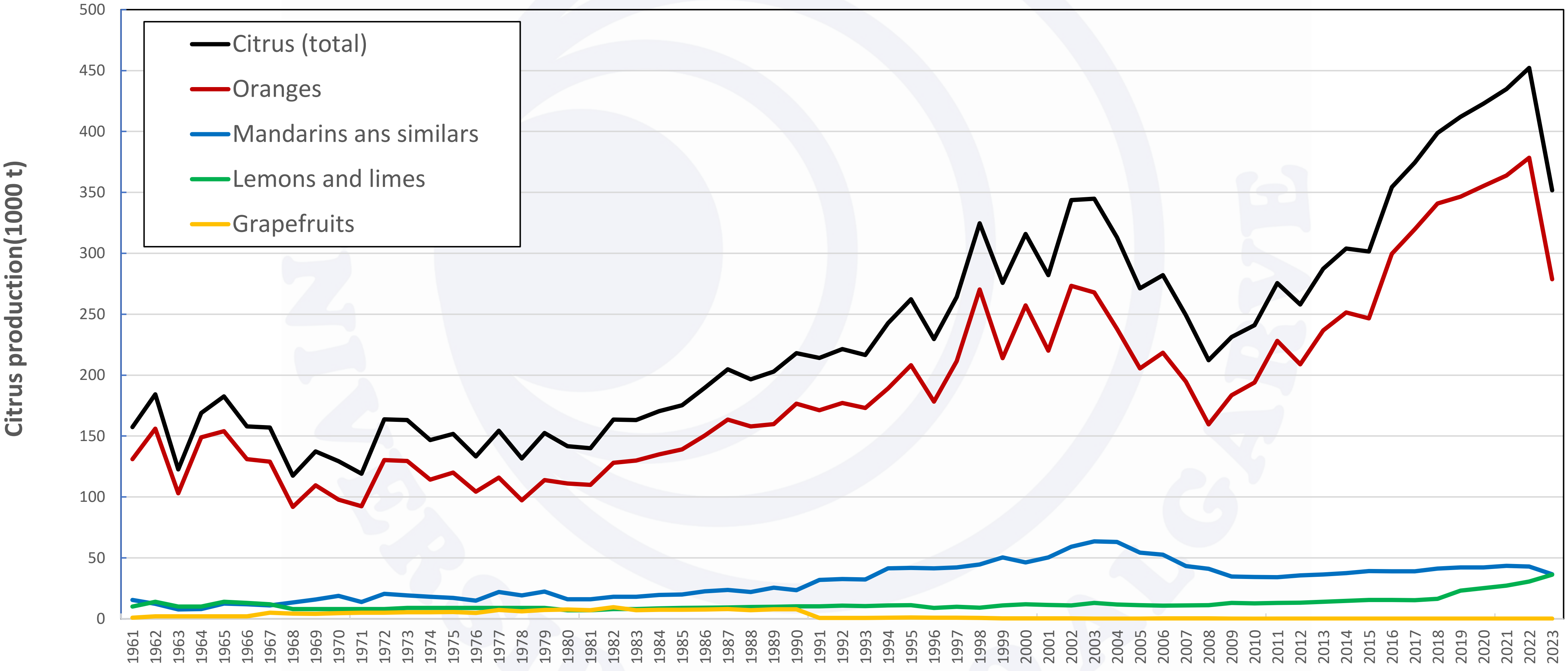
Usos da água



80% de captações particulares

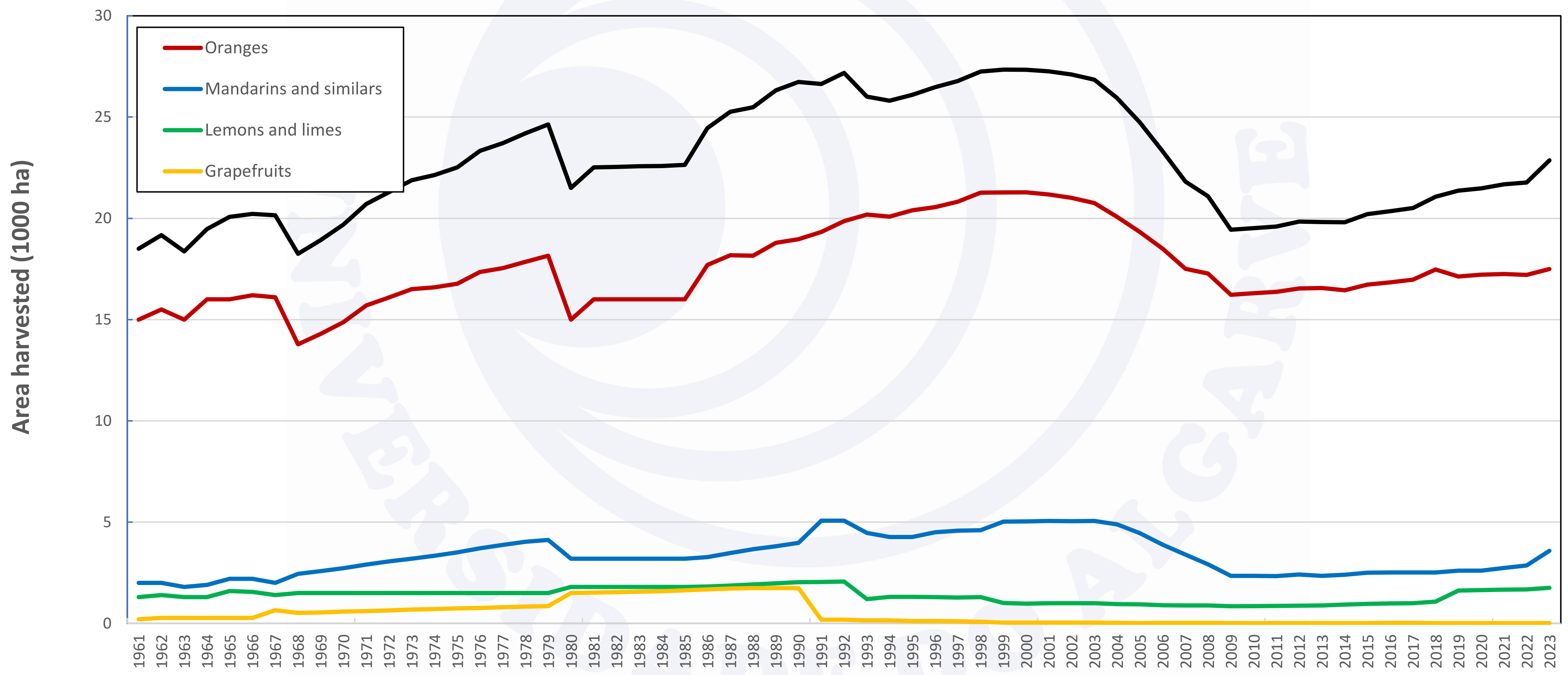
Total ~ 200 hm^3/ano

Evolution of Portuguese citrus industry



FAO, 2025. FAOSTAT: Production: Crops and Livestock Products. Available online: https://www.fao.org/faostat/en/#data/QCL

Evolution of Portuguese citrus industry



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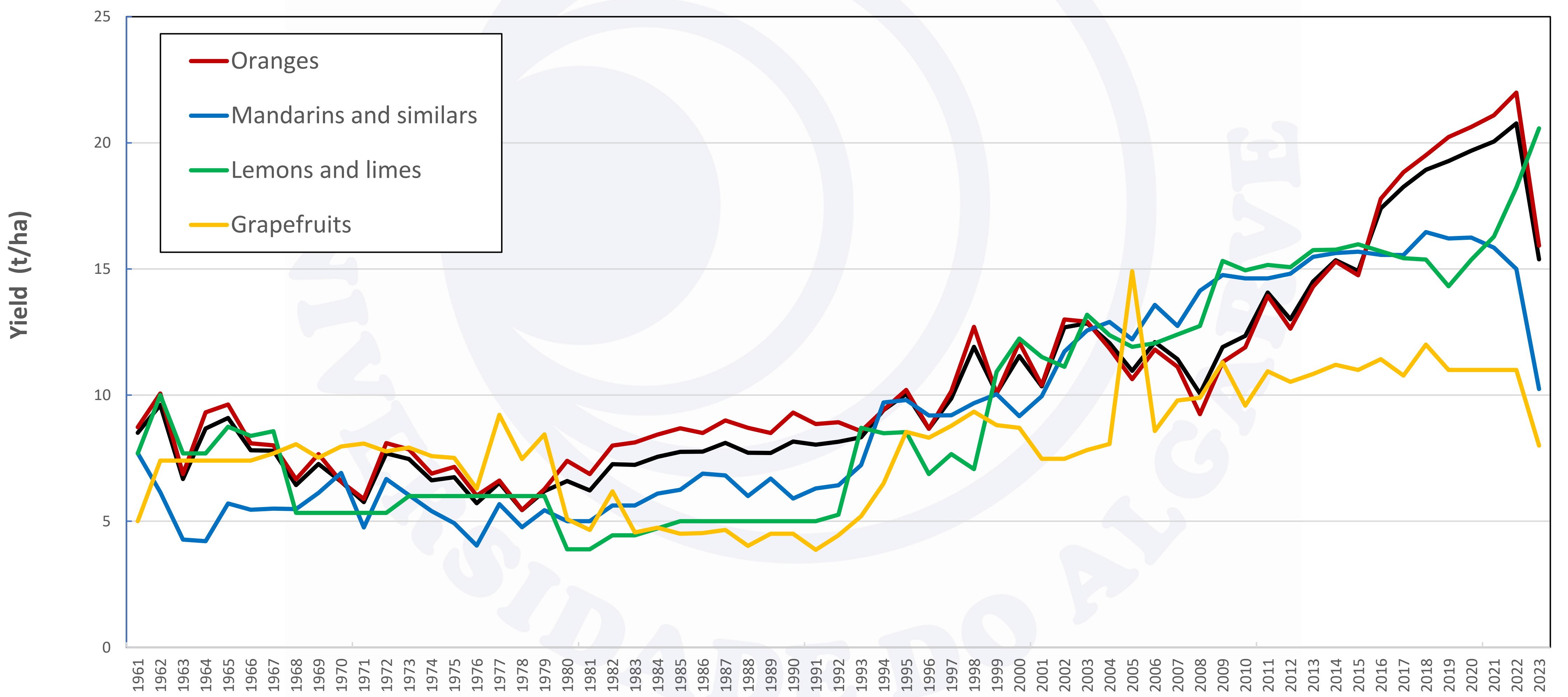
Evolution of Portuguese citrus industry



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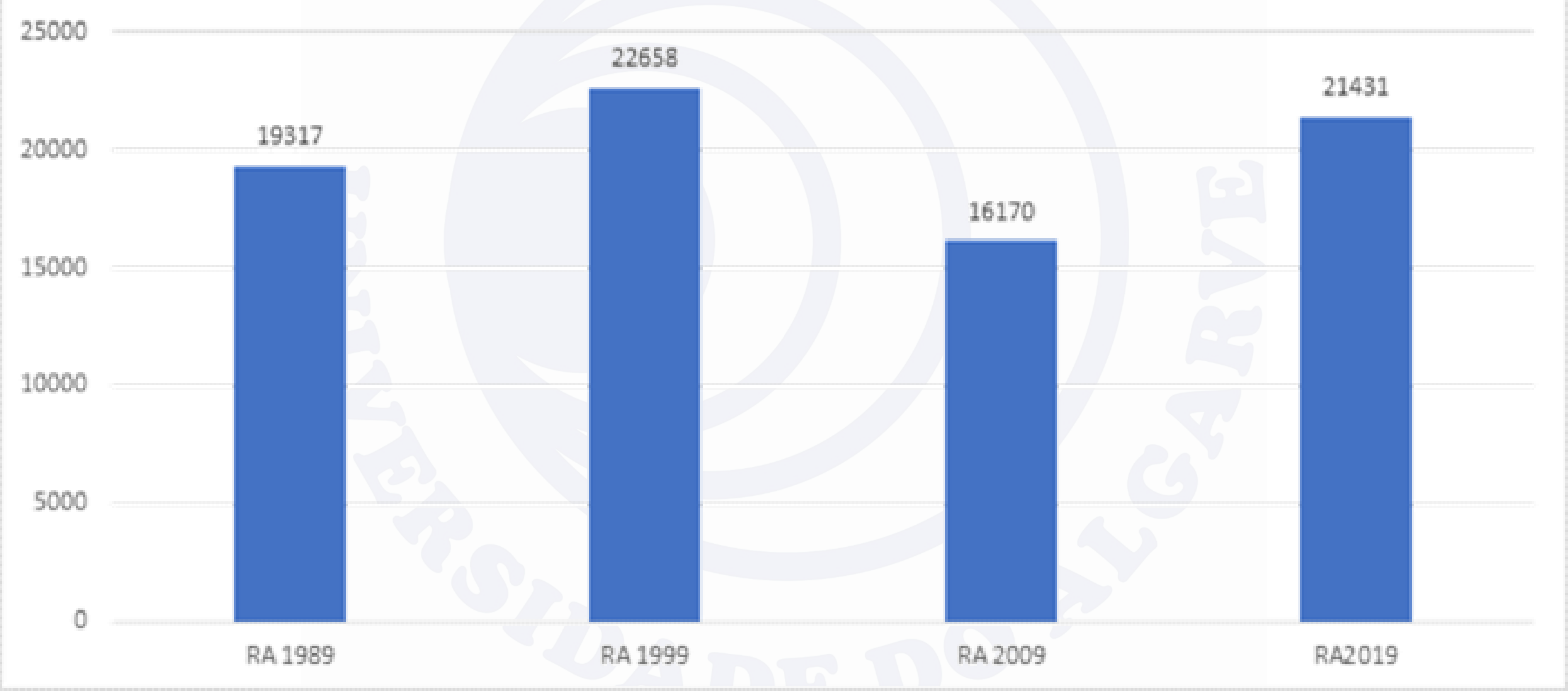
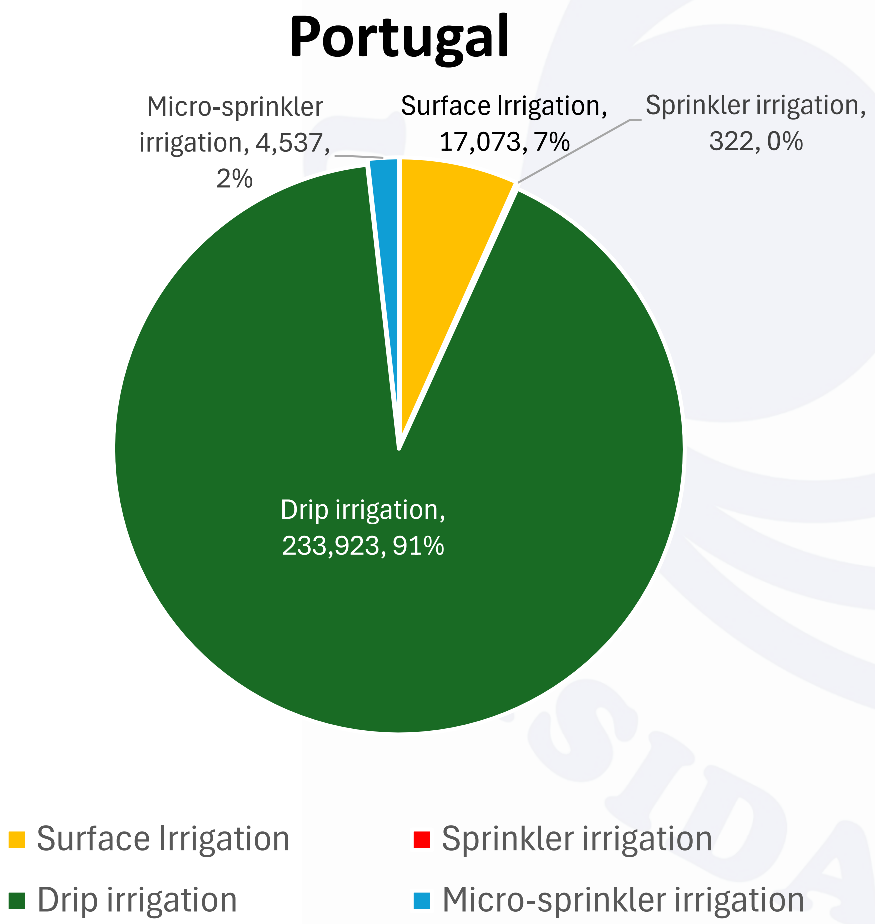
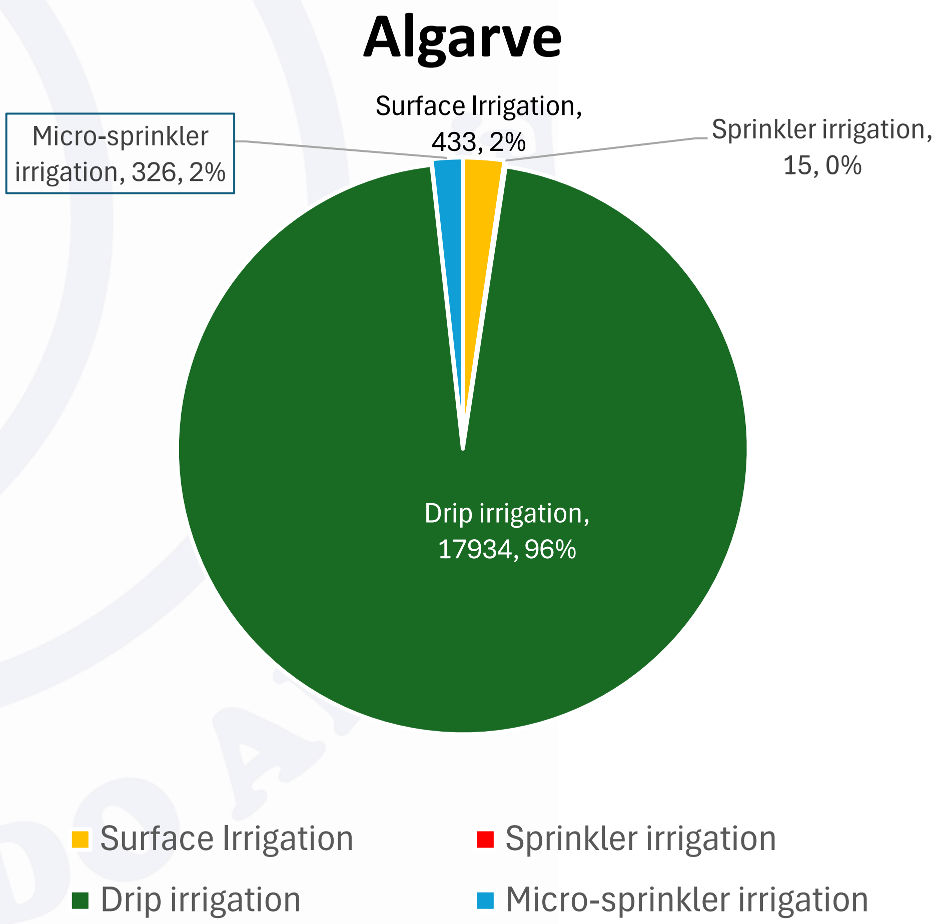
Evolution of the irrigated area in Algarve (ha)

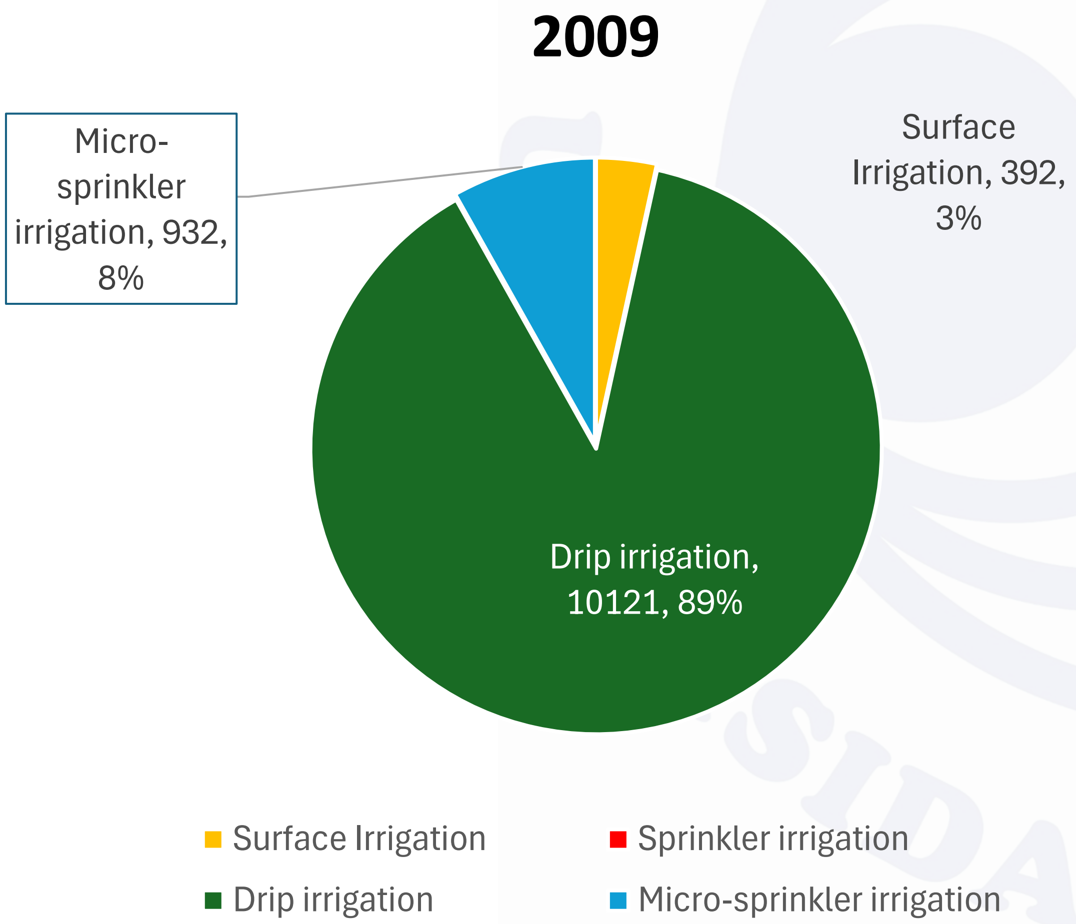


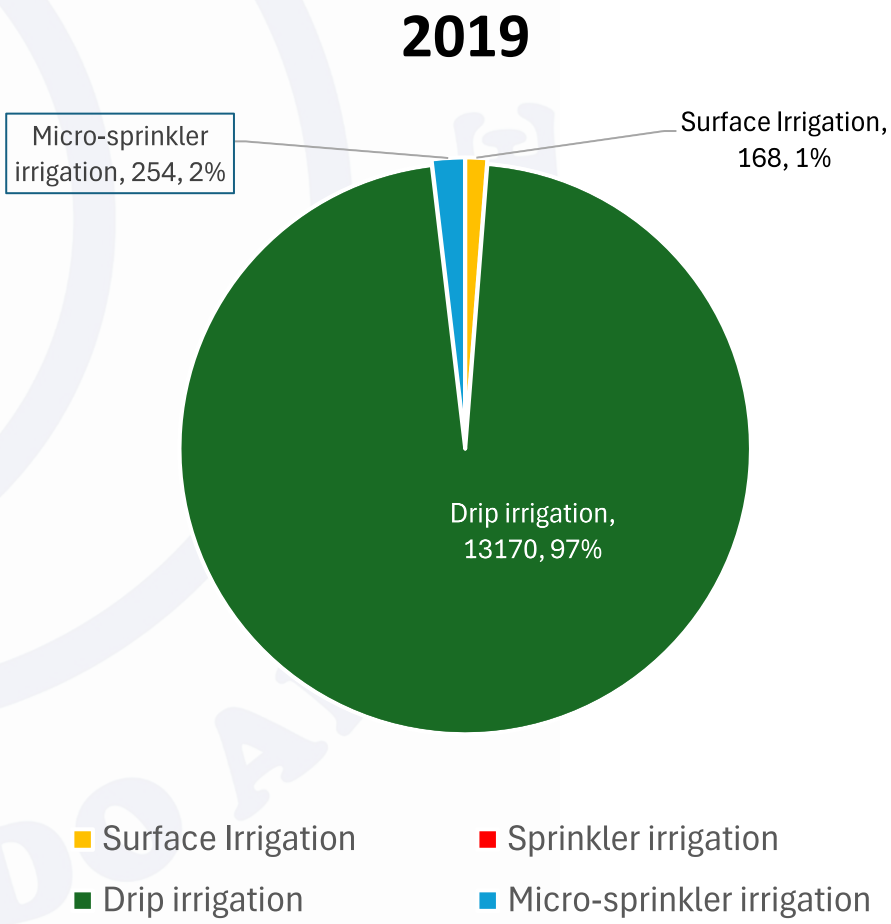
Irrigation methods in permanent crops (2019)





Irrigation methods of citrus orchards in Algarve





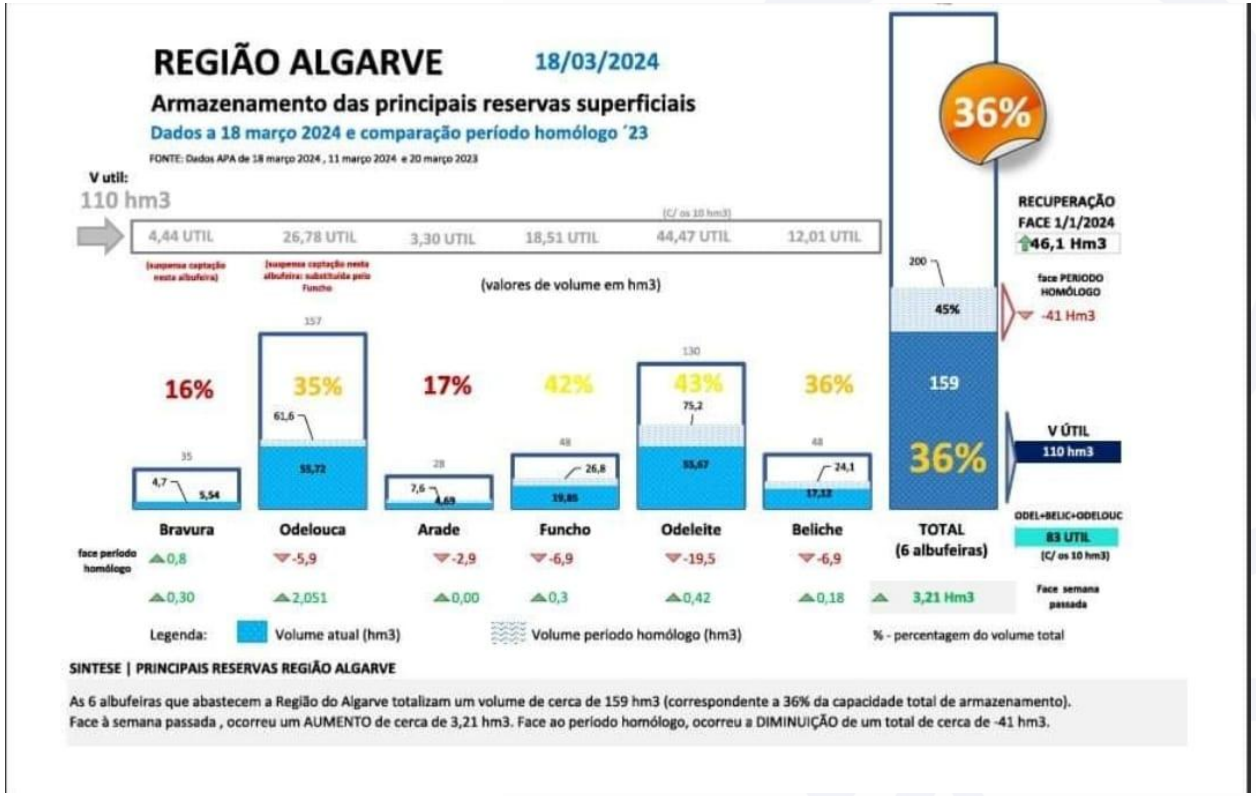
In irrigation, the path was long, but traveled at high speed.

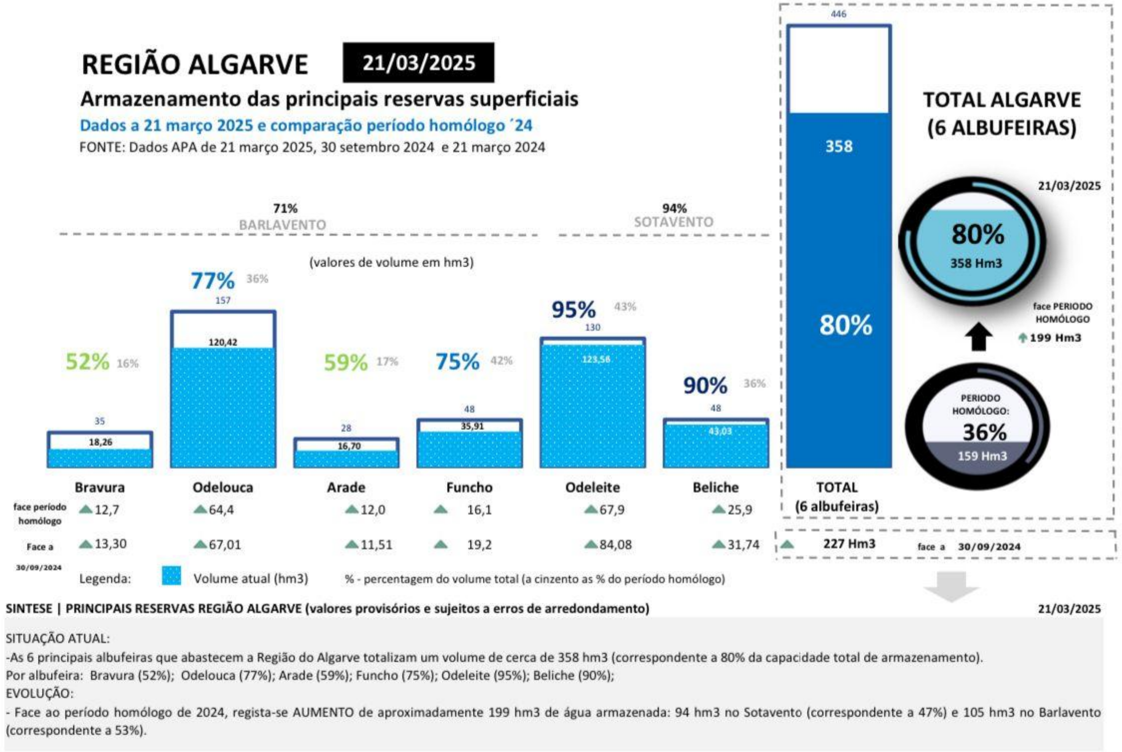
Surface irrigation, in 1955.

Fotografia de Artur Pastor
http://arturpastor.tumblr.com/post/133942398506/cenas-da-vida-rural-benfica-do-ribatejo-1955
(Consultado a 1-01-2016)

In the Algarve, almost all citrus are equipped with a drip irrigation system.

The lack of water in the Algarve is a threat to citrus production (agriculture)





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Article published in 2022

sustainability

MDPI

Article

Urban Wastewater Reuse for Citrus Irrigation in Algarve, Portugal—Environmental Benefits and Carbon Fluxes

Manuela Moreira da Silva [1,2,3], Flávia C. Resende [1], Bárbara Freitas [4], Jaime Aníbal [1,2], António Martins [5] and Amílcar Duarte [4,6,*]

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Caracterização química das águas subterrâneas e do efluente tratado ao longo do período experimental (média ± desvio padrão).

Parameter	Groud water (GW)	Natural Water for Irrigation VMR(1)	Treated effluent(TE)	Quality standard for water reuse (2)
Ammonia mg L^{-1} NH_4^+	0.023 ± 0.020	--	3.92 ± 1.59	10
BOD_5, 20 ºC mg L^{-1} O_2	×	--	10.1 ± 5.3	≤25
B mg L^{-1}	0.08 ± 0.02	0.3	0.16 ± 0.03	--
Ca mg L^{-1}	52.5 ± 1.1	--	34.1 ± 1.1	--
Fe mg L^{-1}	×	5.0	0.44 ± 0.03	2.0
Li mg L^{-1}	×	2.5	0.11 ± 0.01	2.5
Mg mg L^{-1}	51.2 ± 11.4	--	34.9 ± 7.0	--
K mg L^{-1}	35.6 ± 19.4	--	23.4 ± 11.7	--
Na mg L^{-1}	123 ± 6	--	142 ± 25	--
Chlorides mg L^{-1} Cl^-	395 ± 138	70	311 ± 94	--
EC, 20 ºC dS m^{-1})	1.45 ± 0.04	1	1.29 ± 0.23	--
Phosphates mg L^{-1} P	<0.125(3)	--	0.5 ± 0.34	5 (Fósforo total)
Mn mg L^{-1} Mn	×	0.20	0.02 ± 0.01	0.2
Mo mg L^{-1}	×	0.005	0.21 ± 0.15	0.01
Se mg L^{-1}	×	0.02	<0.01(3)	0.02
V mg L^{-1}	×	0.10	<0.01(3)	0.1
Fluorides mg L^{-1}	×	1.0	0.15 ± 0.02	2.0
Nitrates mg L^{-1} NO_3^-	<4(3)	50	4 ± 1	15 (Azoto Total)
Oxidability mg L^{-1} O_2	1.3 ± 0.7	--	×	--
pH Sorenson scale	7.41 ± 0.17	6.5-8.4	7.87 ± 0.14	--
SAR	3.6 ± 0.8	8	4.1 ± 0.6	--
Sulphates mg L^{-1} SO_4^{2-}	217 ± 18	575	171 ± 15	--
TDS mg L^{-1}	1044 ± 163	640	830 ± 166	--
TSS mg L^{-1}	1.0 ± 0.8	60	3.5 ± 1.8	≤35
Turbidity NTU	×	--	7.5 ± 2.4	--
Escherichia coli CFU/100 mL	0 to 2	100	2 to 100	≤100

-- Não referido;
× não quantificado;
(1) Valor Máximo Recomendado na Lei 236/98, Anexo XVI;
(2) Normas de Qualidade constantes da Lei Portuguesa 119/2019 e do Regulamento UE 2020/741, para frutas que não estão em contacto direto com a água de irrigação[54];
(3) Limite de Quantificação;

Carbon emissions related to energy consumption in pumping water for irrigation and fertilisation of orchards.

Water source for irrigation	Power Consumption in water pumping(kW)	Used chemical fertilizers		Carbon emissions	
		Nitrogen kg	Phosphorus kg	kg CO_2e	g CO_2e. kg^{-1} of oranges
Borehole water (ground water)	3449	870	733	858.968	7.32
Treated effluent	1734	76.7	683	431.662	3.68

Advantages of using treated effluents

Benefits in the agroecosystem:

- A irrigation with treated wastewater is **technologically feasible** for watering citrus orchards and
- It can contribute to **improving carbon fluxes**, reduce GHG emissions and promote carbon sequestration.
- **GHG emissions related to orange production may** decrease,
  - Due to **reducing energy consumption for pumping water for irrigation**,
  - **need to apply smaller amounts of synthetic fertilizers**, since the treated effluent has a higher concentration of nitrates and phosphates than groundwater.

Benefits for the soil:

(The **organic matter content** in treated effluents is higher than in groundwater and surface water)

- The use of treated effluents promotes an **increase in soil OM**,
  - **Soil water retention**,
  - Improvement of plant growth
    - Greater carbon sequestration.
    - Greater fruit production

Advantages of using treated effluents

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Other environmental benefits.

- Water reuse **avoids overexploitation** of coastal aquifers, **reducing saline intrusion**
- **Reduces nutrient discharges in the Ria Formosa,** avoiding eutrophication phenomena

- **Potential of citrus orchards to sequester GHGs emitted by urban wastewater treatment plants**, and its potential **contribution to carbon neutrality of urban waste water treatment**.

Limitations

- Location of most WWTPs near the coast (away from orchards and low elevations)
- Need for water transport infrastructure (costs)
- Treatment cost.
- Saltwater intrusion into plumbing systems – water salinity.
- Legal aspects.

PRR-C05-i03-I-000010- Valorization of traditional genetic resources: new crops and irrigation water management in the context of climate change.

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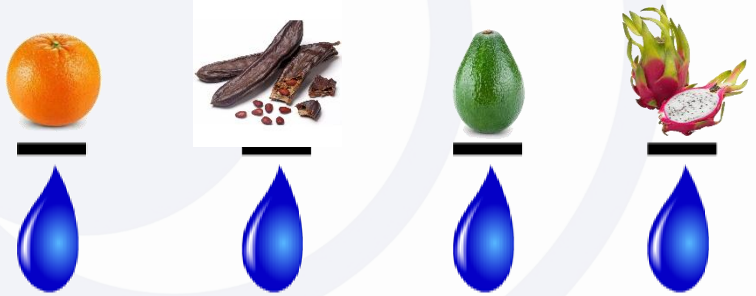

Entidades executoras do projeto

amar a terra – Direção Regional de Agricultura e Pescas do Algarve; UAlg FCT – Universidade do Algarve, Faculdade de Ciências e Tecnologia; MED; AMAL – Comunidade Intermunicipal do Algarve; Frusoal; in LOCO – desenvolvimento e cidadania; COTHN – Centro Operativo e Tecnológico Hortofrutícola Nacional; HUBEL – Engenharia e Sustentabilidade; NUTRIBEAN; Mil Plantas – Produção e comercialização de plantas, Lda.; AGRUPA; CCDM

Financiamento: Este projeto é financiado pela União Europeia através do programa PRR, projeto PRR-C05-i03-I-000010.

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PRR – Plano de Recuperação e Resiliência

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Objectives of the AGRO+EFICIENTE project

- Improve soil fertility and water retention capacity;
- Reduce irrigation doses, with the use of deficient irrigation techniques or soil cover, without reducing productivity;
- Use species and cultivars with economic viability, better adapted to the scenario resulting from climate change;
- Integrate traditional varieties into the production system, making plant material available to the marketing circuits;
- Carry out promotion, awareness, dissemination, training and editing of publications to communicate the objectives of the projects.

Regulated deficit irrigation (RDI) trial on avocado

- Cultivar: 'Hass'
- Orchard age: 6 years
- Planting density: 6x4
- Farmer: Diamantino Trindade (Cacela Velha);
- Treatments:
  - CDI: Conventional drip irrigation (100%-ETC);
  - RDI-10: 90%-ETC;
  - RDI-20: 80%-ETC;
  - RDI-30: 70%-ETC.
- Irrigation reduction period: August to October 2024
- Trial assessments:
  - Monitoring of fruit growth, SPAD index, and productivity.
  - Monitoring of soil moisture levels using installed soil probes.
  - Collection of soil samples to determine soil microbiology.

Trial's experimental design.

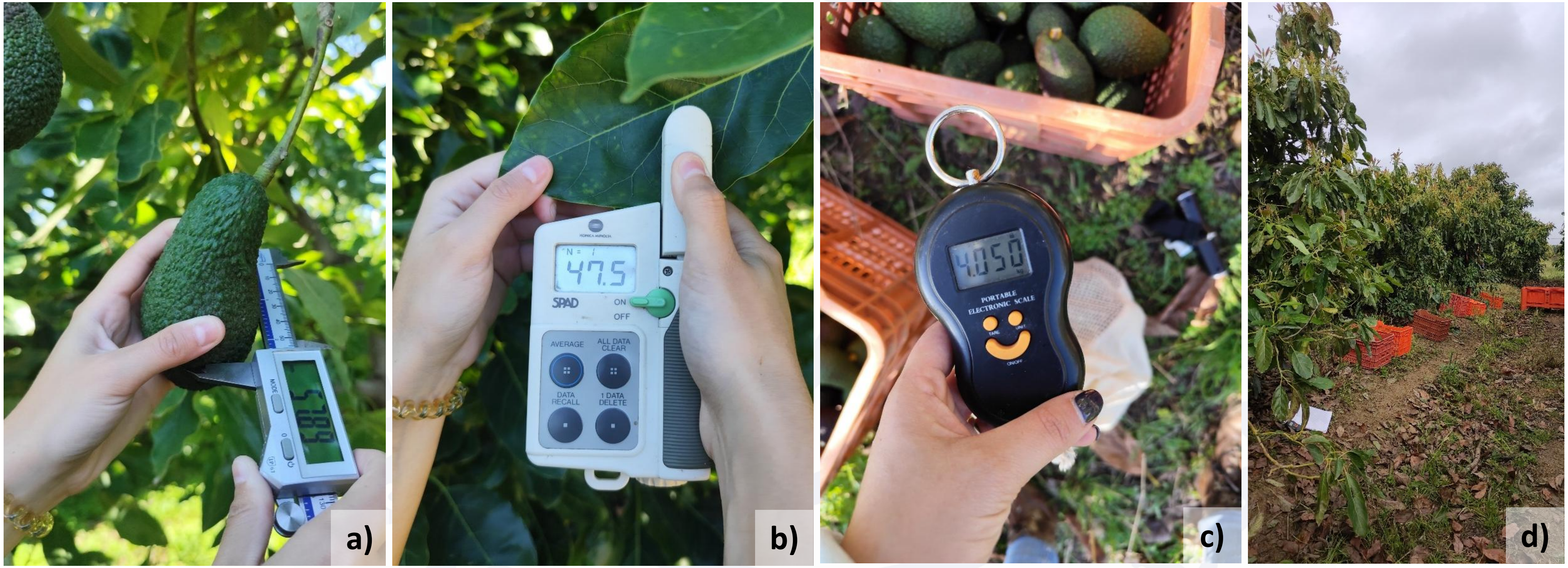
Regulated deficit irrigation (RDI) trial on avocado

Installation of the RDI trial in avocado orchard, including the water flow meters used to verify the water used for each treatment.

Regulated deficit irrigation (RDI) trial on avocado

Soil moisture monitoring probes: (a) access tubes for the Diviner-Sentek 2000, and (b) Drill&Drop probes for continuous measurements.

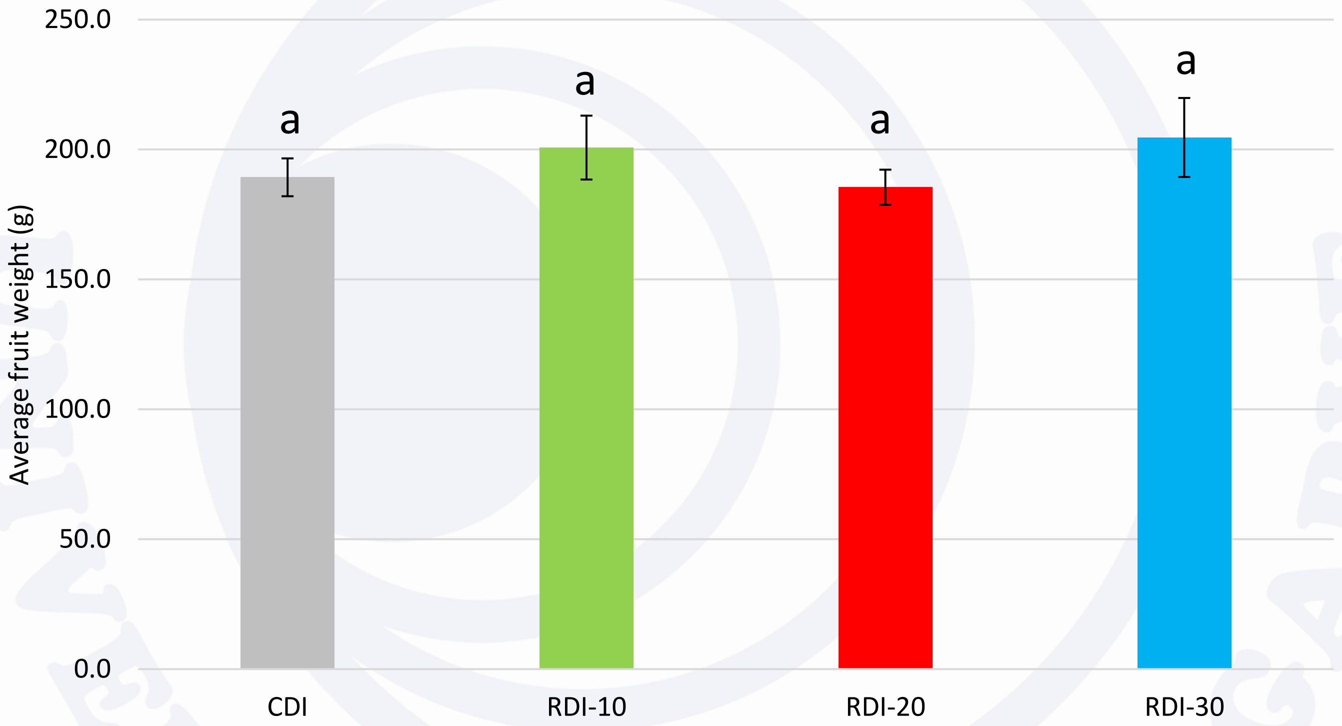
Regulated deficit irrigation (RDI) trial on avocado



Monitoring of fruit growth (a), SPAD index (b), harvest tracking to determine average fruit weight (c), and yield per tree (d).

Regulated deficit irrigation (RDI) trial on avocado

Preliminary results from the first year of the regulated deficit irrigation (RDI) trial in avocado under the soil and climate conditions of the Algarve.



Effect of regulated deficit irrigation (RDI) on the average fruit weight of avocado (g).RDI was applied from August 15 to October 8, 2024, resulting in water savings of 518.4 liters per tree for the RDI-10 treatment, 1036.8 liters per tree for RDI-20, and 1555.2 liters per tree for RDI-30.CDI = conventional irrigation ($ET_0 \times Kc$);RDI-10 = regulated deficit irrigation with 10% water savings;RDI-20 = regulated deficit irrigation with 20% water savings;RDI-30 = regulated deficit irrigation with 30% water savings. Values with the same letters showed no statistically significant differences ($p < 0.05$), according to Duncan's multiple range test.

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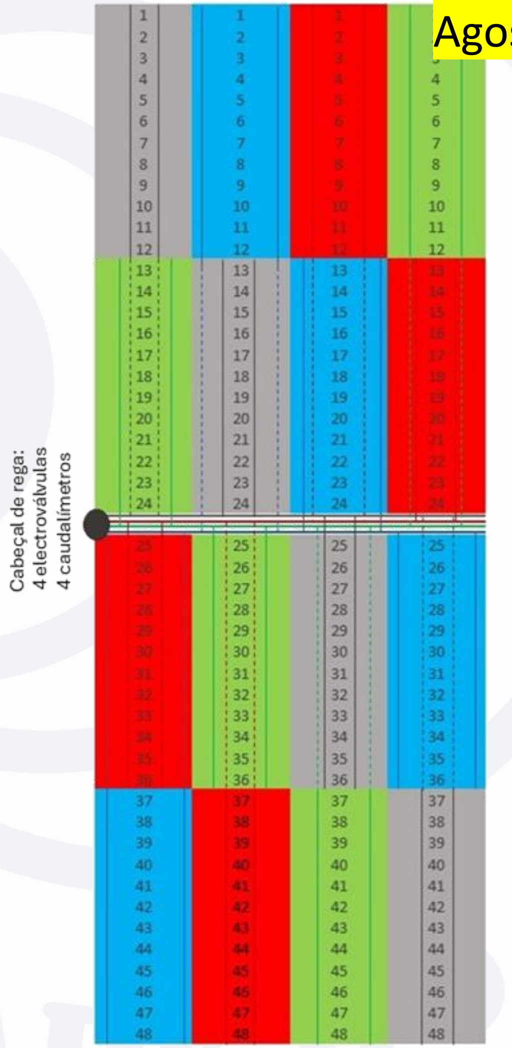
Regulated deficit irrigation (RDI) trial on citrus

Os resultados do primeiro ano de ensaio só vão ser obtidos com a monitorização da colheita de Agosto/setembro 2025.

- Cultivar: 'D. João' (Orange trees)
- Orchard age: 9 years old
- Planting density: 6x3,5
- Farmer: Frusoal (Cacela Velha)
- Treatments
  - CDI: Conventional drip irrigation (100%-ETC);
  - RDI-10: 90%-ETC;
  - RDI-20: 80%-ETC;
  - RDI-30: 70%-ETC.
- Irrigation reduction period: After June fruit drop until pre-harvest.
- Trial assessments:
  - Monitoring of fruit growth, SPAD index, and productivity.
  - Monitoring of soil moisture levels using installed soil probes.
  - Collection of soil samples to determine soil microbiology.



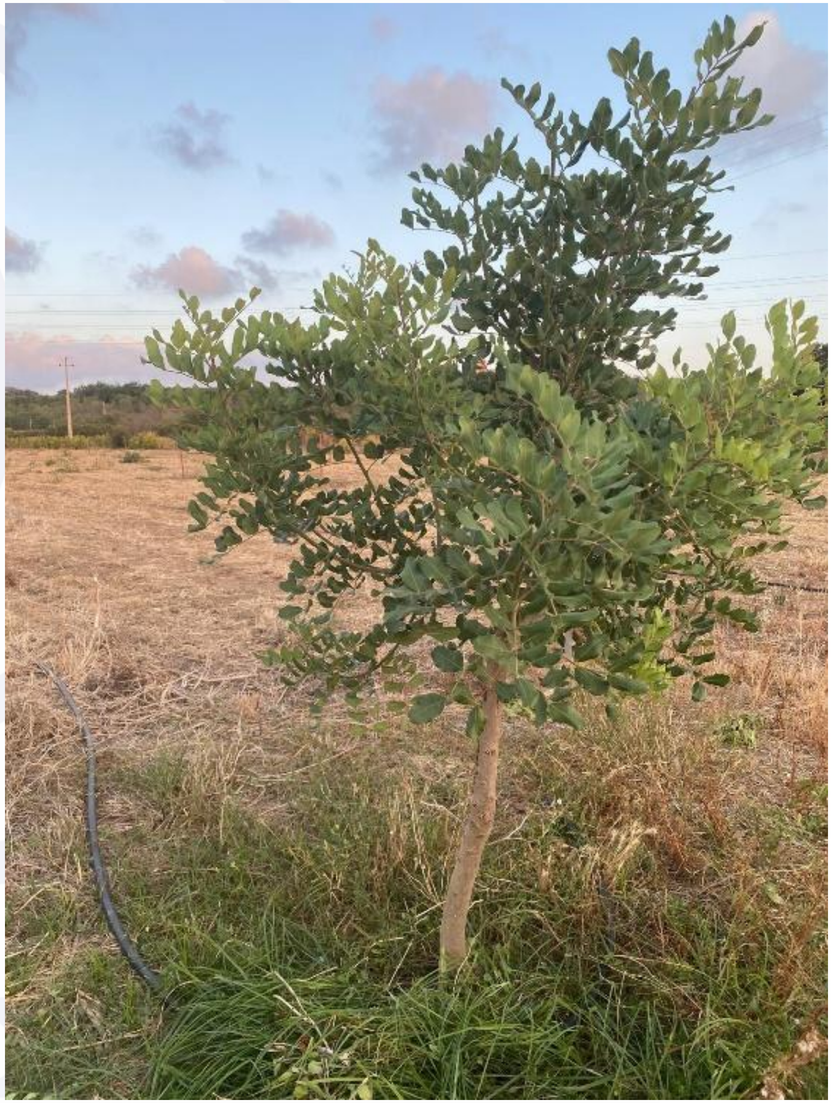
Experimental design of the trial and harvest monitoring for year 0.

Regulated deficit irrigation (RDI) trial on citrus

Installation of the RDI trial in citrus orchard, including the water flow meters used to verify the water used for each treatment.

Regulated deficit irrigation (RDI) trial on carob trees

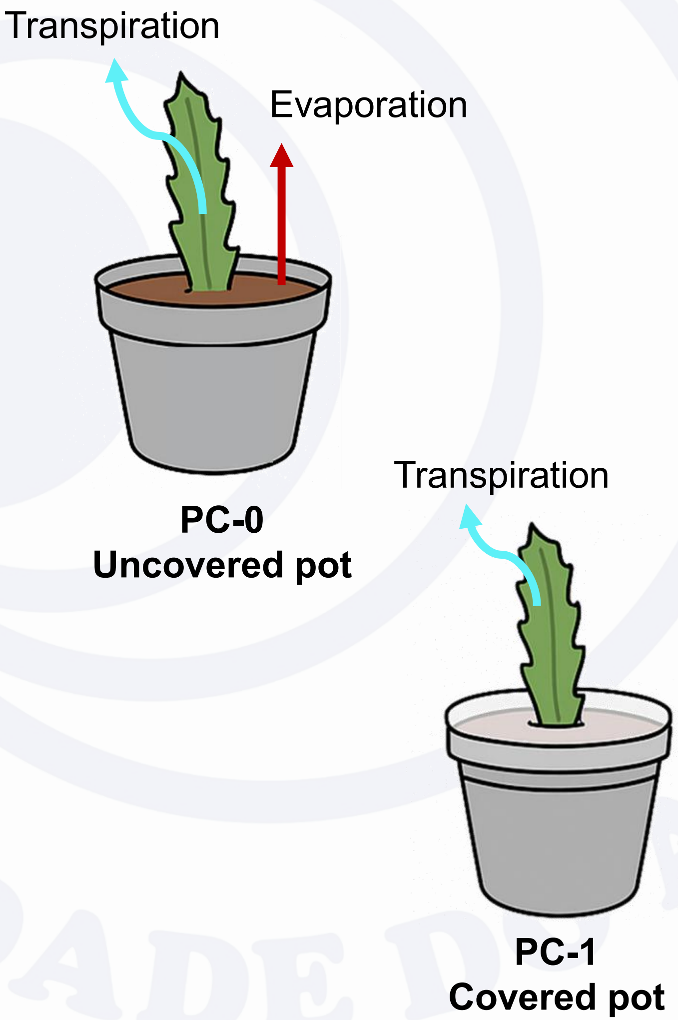
- Orchard age: 4 years
- Graft: 2023 and 2024
- Farmer: Mafalda Sales-Gomes (Meloal, Faro)
- Treatments:
    - T1: Coventional drip irrigation (100%-ETC)
    - T2: RDI-25 (75%-ETC)
    - T3: RDC-50 (50%-ETC)
- Irrigation reduction period: June to October 2024
- Trial assessments:
    - Monitoring the growth of the grafted shoot, the diameter of the stem and the SPAD index.



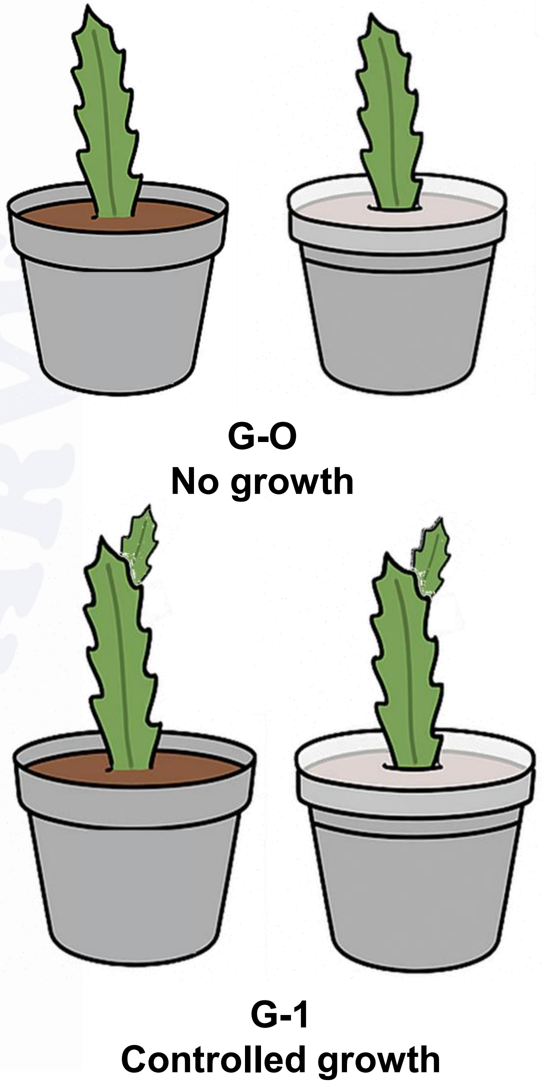
Average daily water consumption (DWC) of pitaya

- Crop: Pitaya (*Selenicereus undatus*).
- Trial location: University of Algarve.
- Methods:
  - Using a weighing lysimeter to measure average daily water consumption (DWC) in pot-grown pitaya plants.
  - Evapotranspiration was measured in uncovered pots, while covered pots assessed plant transpiration.
  - The impact of new vegetative growth on transpiration and evapotranspiration was also assessed.
- Trial period: summer and winter.

To assess crop evapotranspiration



To assess the effect of new growth



Average daily water consumption (DWC) of pitaya

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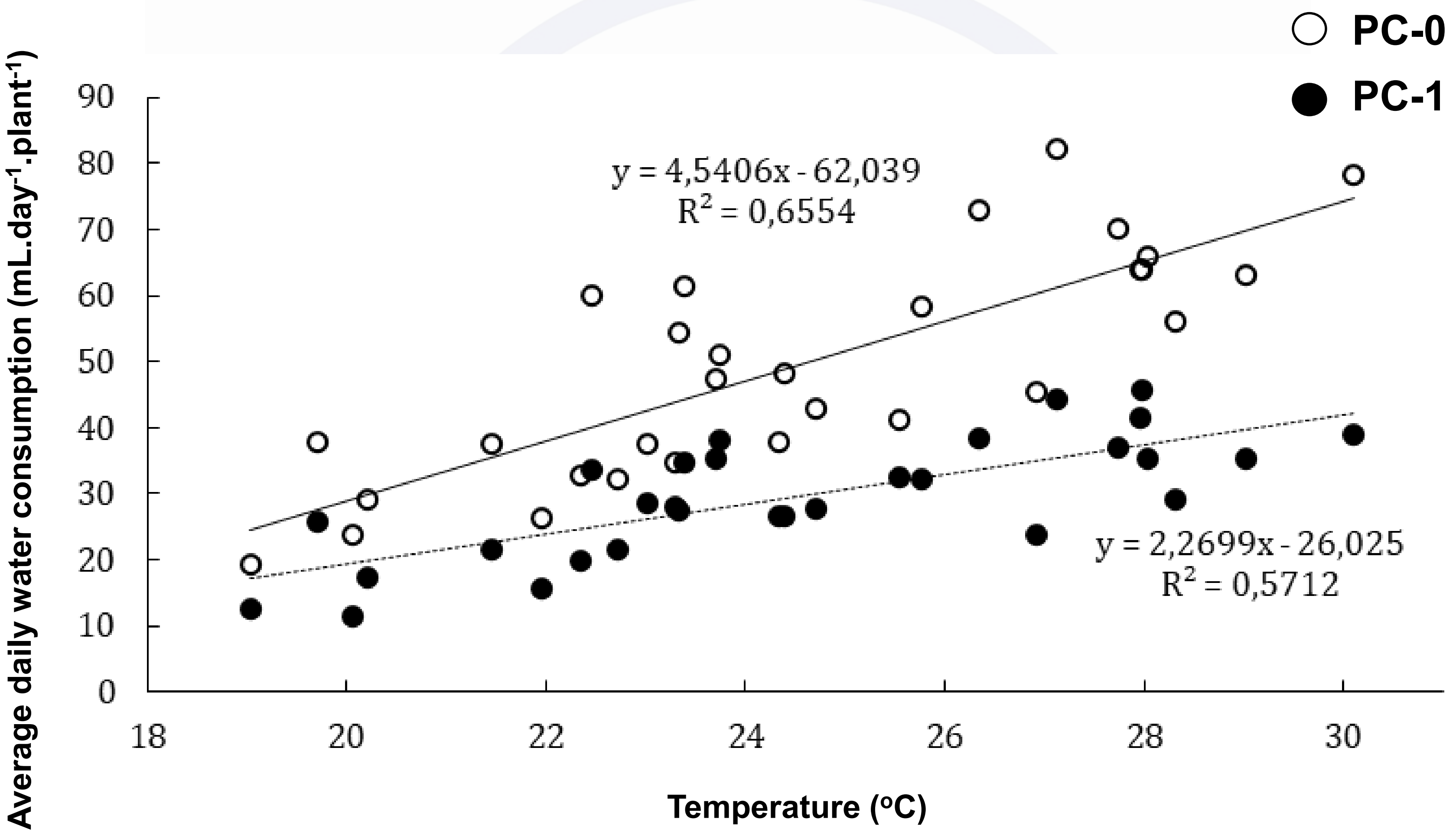
- Trial assessements:
  - The pots were weighed before and after watering using a floor scale (a); a known volume of water was applied (b); and for the growing plants (G-1), the single retained vegetative shoot was measured (c).

a)

b)

c)

Average daily water consumption (DWC) of pitaya



Effect of daily mean temperature on daily water consumption in evapotranspiration (PC-0) and transpiration (PC-1) of pitaya plants.

Greenhouse trial to determine the average daily water consumption of dragon fruit

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This study revealed that :

- Dragon fruit exhibited remarkably low water use, confirming that its overall evapotranspiration is considerably lower than that of other irrigated fruit crops..
- A significant portion of the total evapotranspiration was attributed to evaporation from bare substrate.
- Daily water consumption is largely independent of pitaya plant growth.
- These results contribute to a better understanding of the water needs of dragon fruit and highlight its exceptional water use efficiency, reinforcing its suitability for cultivation in Mediterranean climates..

The Agro+Eficiente team

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Obrigado

Thank you

Σας ευχαριστώ