First Watermelon Experiment in an Agrivoltaic Greenhouse in Southern Spain

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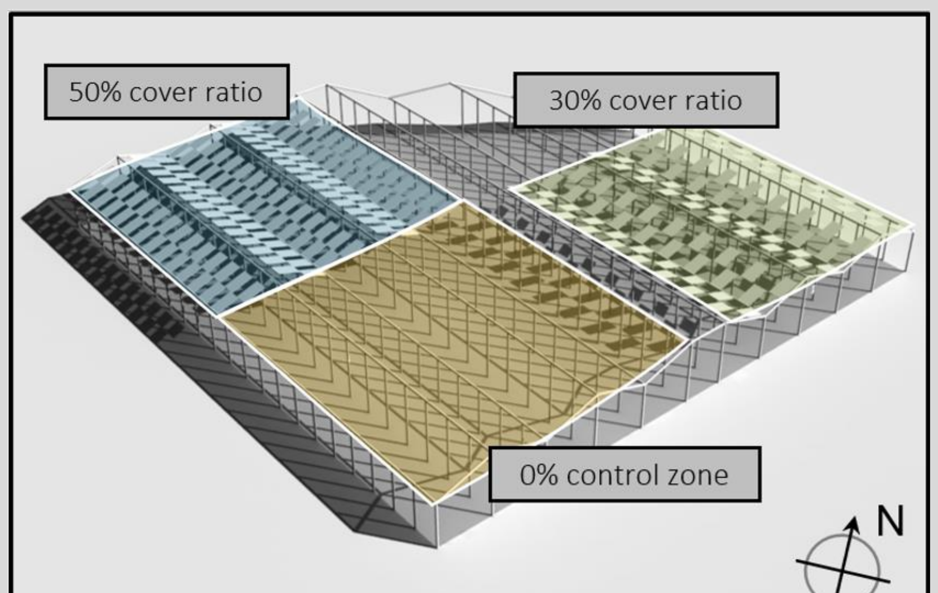
Introduction

- Watermelons play significant role in fruit market, Spain covering ~35% in EU[1]
- Farmers face significant challenges due to market volatility and dependence on fluctuating prices
- In greenhouse watermelon cultivation, APV could optimize resource efficiency
- Limiting factor for working conditions and photosynthetic assimilation of plant canopy in greenhouses in Spain is high temperatures in summer[2]
- We here present: effects of artificial shading on watermelon yield + microclimate dynamics in first experiment conducted in Almería, Southern Spain

Experimental Setup

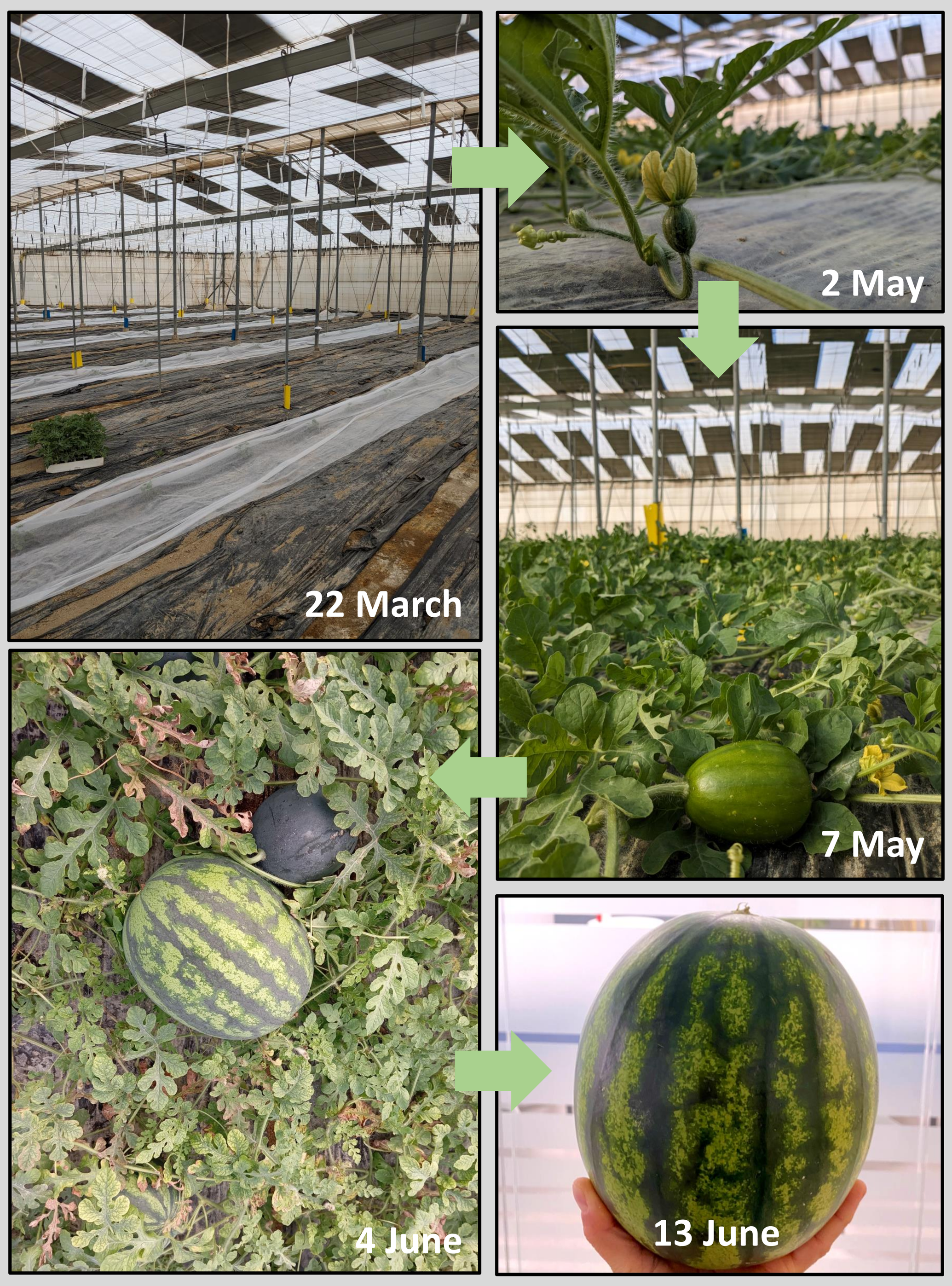
- Commercial scale "Raspa y amagado" greenhouse
- Two zones shaded in checkerboard pattern (30 and 50%), one reference zone
- Continuous measurements of global horizontal irradiance (GHI), photosynthetically active radiation (PAR), temperature (T), rel. humidity (RH), 0.5m height

Experimental greenhouse at Finca UAL-ANECOOP



Virtual copy by DLR agrivoltaic simulation model[3]

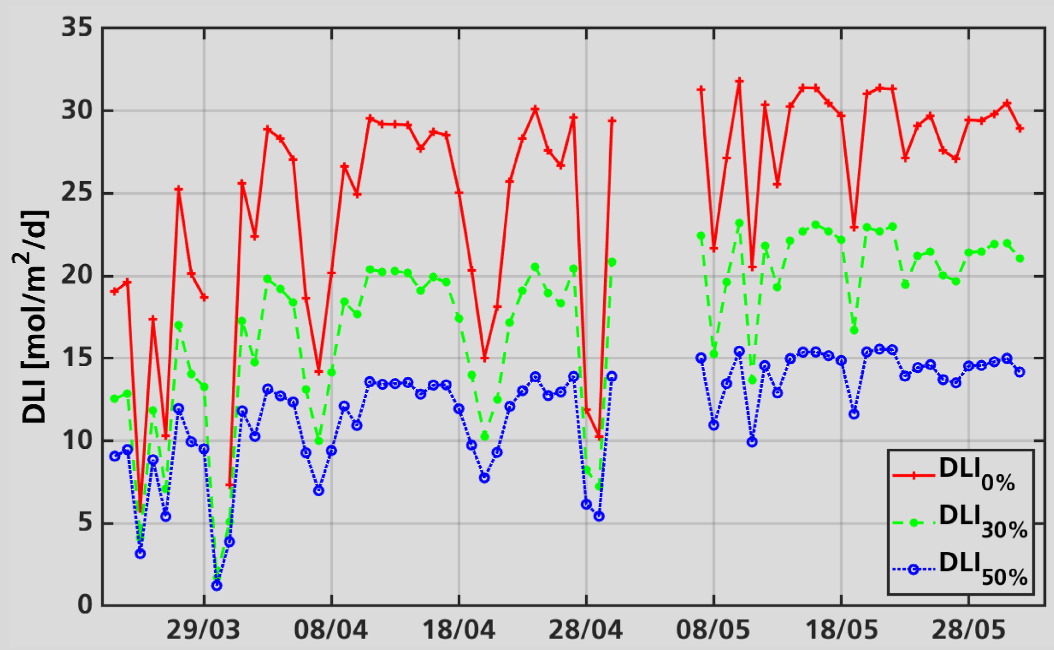
- Cultivation of watermelon 22 March-12 June 2024
- Diploid watermelon variety with microseeds under development by ANECOOP



Results

Irradiance pattern

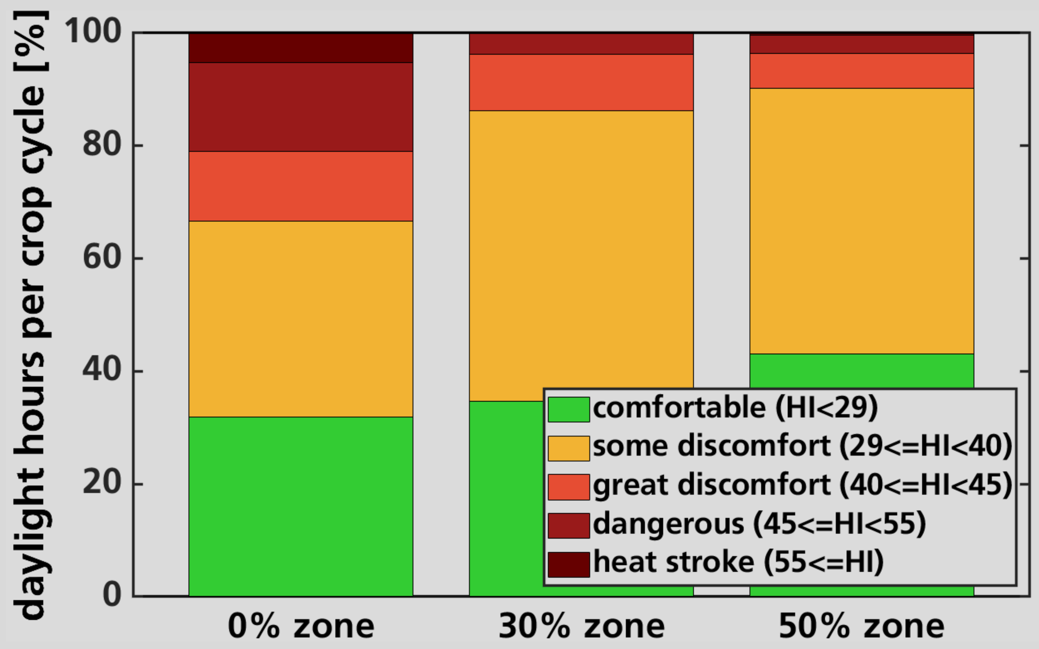
- Watermelon are high light demanding crops → sufficient DLI levels > ~12 mol/m²/d [4]
- Daily light integral (DLI) derived from measured global horizontal irradiance (GHI) and photosynthetically active radiation (PAR, 400-700nm, ECO ML-020P-SET-05) in 0.5m height
- DLI reduction ~29.4% lower in 30% shading, ~51.7% in 50%, compared to 0% zone
- DLI> 12 mol/m²/d on most days (also 50% shading)
- DLI increased across all zones towards summer



DLI, 22 March - 2 June 2024 for 0% shaded zone (red), 30% shaded zone (green) and 50% shaded zone (blue)

Microclimate and Working Conditions

- Working conditions in plastic greenhouses must be carefully considered due to high temperatures + humidity affecting worker health and productivity
- The Heat Index [5,6,*] (HI) combines temperature and humidity to assess heat stress
- $\mathrm{HI} = c_1 + c_2T + c_3RH + c_4T * RH + c_5T^2 + c_6RH^2 + c_7T^2 * RH + c_8T * RH^2 + c_9T^2 * RH^2$
- ~31% of daylight hours in 0% zone are comfortable, ~35% in 30% zone and 43% in 50% zone



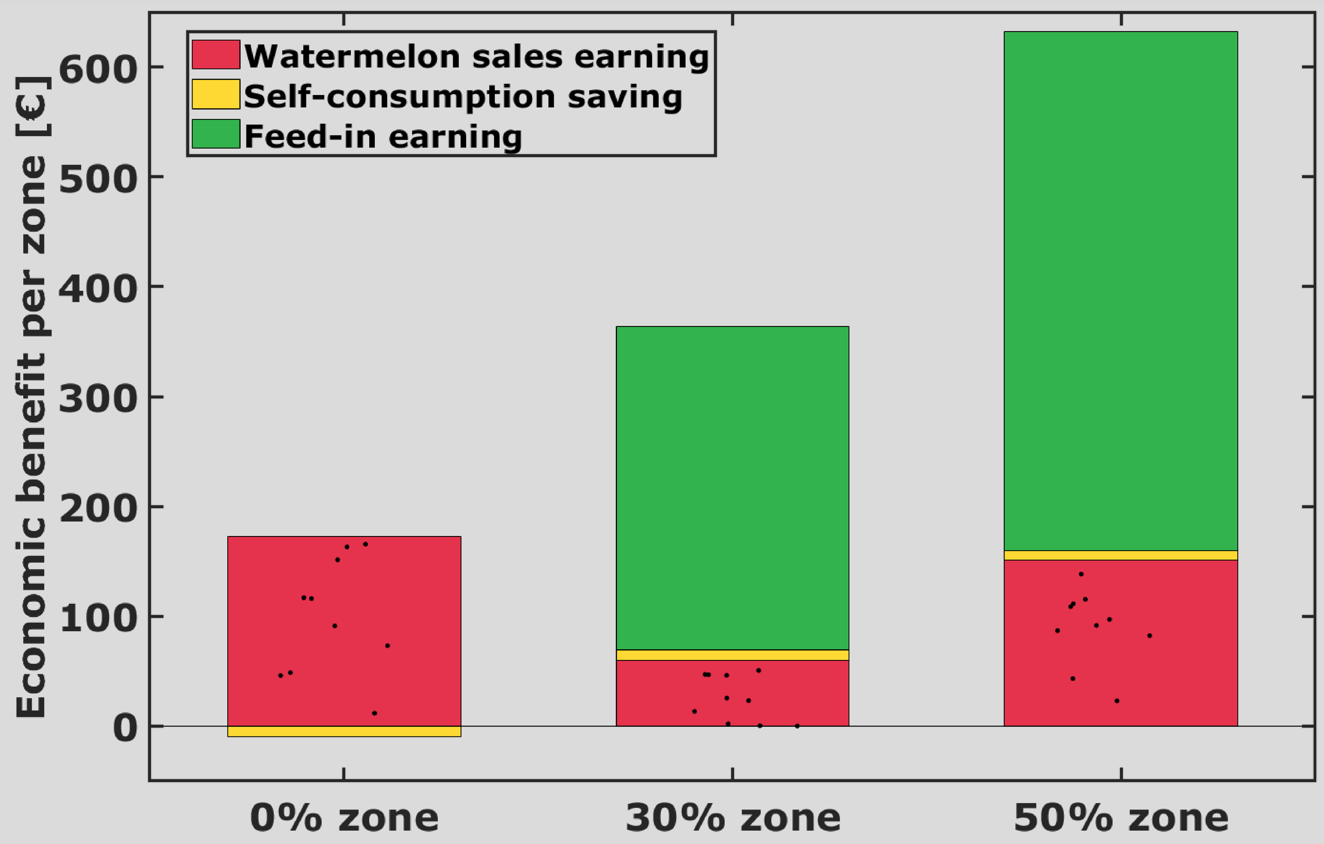
HI limits adapted from [6]

Crop yield and quality

- Crop yields in 0% (509kg) and 50% (444kg) zones of similar scale
- <u>But:</u> significantly lower in 30% zone (177kg) → disease powdery mildew (due to soil infection) → Plant health can be „all or nothing" factor → early disease detection crucial to prevent crop losses + maintain fruit quality
- Fruit color, firmness and °Brix → all zones showed similar results

Economic consideration

- Market price in Spain fluctuates significantly during season and year (between 0.06-0.96€/kg[7] since 2024), also dependent on average temperatures in Central Europe[8]→ income uncertainty for farmers
- Assumptions for study:
  - Watermelon market prize 0.34€/kg, week 24, 2024[7]
  - Monthly electricity prizes for self-consumption and feed-in for March-June[9,10,11]
  - OPEX and CAPEX not considered here



→ Theoretical PV energy output would completely cover estimated self-consumption per zone
→ Savings from covered electricity costs would already compensate ~40% of reduced crop income in 50% zone
→ Feeding surplus electricity into grid: Overcompensates watermelon sales losses even in 30% zone (disease case)
→ Extra financial security for farmers due to additional income from feeding surplus generated electricity into grid → particularly in cases of disease outbreaks like in the 30% zone

Conclusions

- First agrivoltaic watermelon experiment performed from March to June 2024 in Almería, Spain
- Improved shading strategies increase working conditions within *raspa y amagado* plastic greenhouses
- Benefit for farmers due to added financial security → income gain due to electricity feed-in earning additionally to watermelon sales earning

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*c1 = -8.78; c2 = 1.61; c3 = 2.34; c4 = -0.15; c5 = -0.01; c6 = -0.02; c7 = 2.21e-3; c8 = 7.25e-4; c9 = -3.58e-6;

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