UNIVERSITY OF HOHENHEIM

Institute of Agricultural Sciences in the Tropics (Hans- Ruthenberg-Institute) Water stress Management (490g)

Effects of irrigation scheduling on soil moisture and water use efficiency in quinoa

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Introduction

Increasing water scarcity in semi-arid regions requires irrigation strategies that reduce water inputs while maintaining crop productivity.

Quinoa (*Chenopodium quinoa* Willd.) is adapted to water-limited environments, yet efficient production requires appropriate irrigation scheduling. Sensor-, model- and weather-informed approaches may provide alternatives to conventional farmer's practice.

We compared six irrigation strategies under field conditions in northeast Morocco to assess their effects on water use, crop growth and yield.

Conclusions

- Reduced irrigation did not necessarily compromise crop performance, indicating potential for substantial water savings.
- Soil water depletion occurred mainly in the upper soil profile, emphasizing the importance of irrigation depth.
- Sensor-based scheduling balanced water savings and crop performance best, while model-based approaches performed poorly.
- Strong seasonal variation in rainfall needs to be considered when evaluating and adapting irrigation strategies under semi-arid conditions.

Results and Discussion

- **Water input:** Compared with farmer's practice, irrigation input was significantly lower under sensor (−36%), AI (−38%), DC (−70%), and DI (−76%). CROPWAT was essentially the same as farmer's practice (-0.4%).
- **Yield:** Grain yield was significantly lower under AI and DC than farmer's practice, while DI, sensor & CROPWAT did not differ significantly from farmer's practice.
- **Biomass:** Irrigation strategy did not significantly affect biomass.

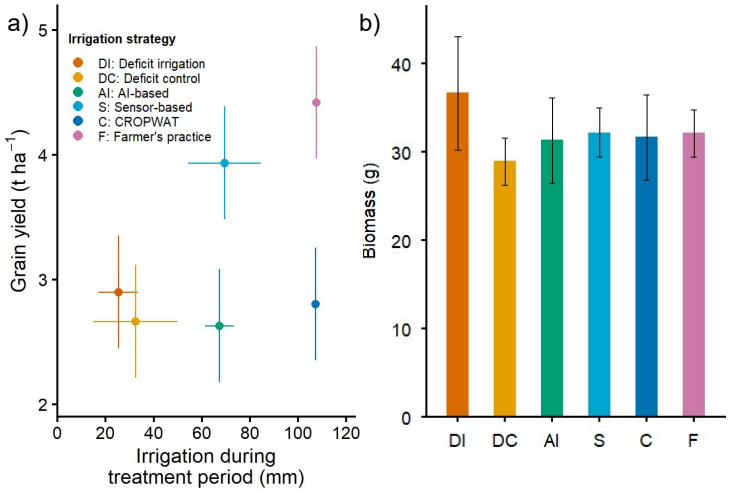

Figure 1. Effects of different irrigation strategies on (a) Grain yield in relation to irrigation amounts. Points represent observed mean irrigation amounts and model-adjusted grain yield. Horizontal error bars indicate ±SE of observed irrigation amounts and vertical error bars model-based ±SE of grain yield. (b) Total plant dry weight (g) at harvest. Bars represent mean biomass per planting position, with error bars indicating ±SE.

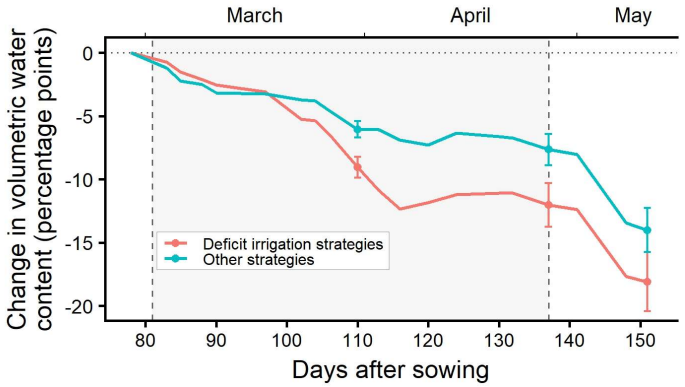

Figure 2. Change in PR2-measured volumetric water content at 30 cm relative to the pre-treatment baseline (DAS 78) under deficit irrigation strategies (DI + DC) and other irrigation strategies (AI, CROPWAT, farmer's practice and sensor-based irrigation). Points and error bars show mean ± SE at DAS 110, 137 and 151. The shaded area indicates the irrigation treatment period (DAS 81–137); dashed lines mark its start and end.

- **Soil moisture:** Deficit strategies showed stronger depletion than the other strategies; depth analysis indicates the response was stronger at 30–40 cm than at 60 cm.

Table 1. Monthly precipitation during the growing season compared with the long-term average.

Month	Average precipitation 1998-2024 [mm]	Precipitation 12/2025 – 05/2026 [mm]	Difference [mm]
December	31.9 ± 24.3	84.3	+52.4
January	46.8 ± 47.6	69.4	+22.6
February	31.5 ± 31.1	24.4	-7.1
March	41.3 ± 50.9	9.7	-31.6
April	34.6 ± 35.6	35.4	+0.8
May	23.1 ± 23.6	0.0	-23.1

Materials and Methods

- Quinoa 'Titicaca' & 'ICBA Q5' cultivated for 6 months using drip irrigation (11.12.25-12.05.26) in Berkane, Morocco
- Resolvable row–column design with three complete blocks (replicates); application of treatments: after flowering (81 – 137 Days after sowing)
- Irrigation scheduling strategies included FAO software CROPWAT, Sensor-based (Dragino soil moisture sensors), Deficit irrigation (DI), Deficit irrigation control (DC), AI model combined with sensors & Farmer's practice
- Soil moisture was measured at 10, 20, 30, 40, 60 and 100 cm depth 2-3 times per week in each plot using a PR2 probe (Delta-T) during the entire crop duration

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