Optimizing water productivity for Menara olive cultivar: exploring the impact of regulated and sustained deficit irrigation strategies in Morocco

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Abstrat. The agricultural sector in Morocco faces drought challenges due to limited water resources, necessitating the development of irrigation strategies targeted at increasing water production. In this regard, the olive sector can adopt deficit irrigation strategies, to achieve sustainable management practices that improve water productivity and save water used for irrigation. In pursuit of this aim, an experiment was carried out in an olive orchard over two consecutive years (2021 and 2022), comparing water productivity (WP) of four treatments of regulated deficit irrigation (RDI) and two treatments of sustained deficit irrigation (SDI), with fully irrigated trees. The results indicated that over time the RDI strategy, particularly in the T4 treatment, makes it feasible to conserve a substantial amount of irrigation water, approximately 40% during the phase when pit hardening occurs, and 20% during sensitive periods, all without compromising fruit yield. However, the SDI strategy, with its limited water availability, leads to a decline in the fruit yield of Menara olive trees. Out of these treatments, the SDI strategy led to the most substantial decrease in WP, with reductions ranging from 19% to 33% compared to the control T0.

Keywords: Olive tree, regulated deficit irrigation, sustained deficit irrigation, water productivity

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1 Introduction

Morocco is facing significant challenges caused by drought conditions, mainly because agriculture is the country's primary economic and social growth lever, while water resources are limited and face growing competition for agricultural and domestic purposes (1). Indeed, agriculture and water resources stand out as two pivotal sectors in Morocco and at the same time, the most influenced by extreme climate changes and variations. Moreover, drought stress presents significant challenges to multiple sectors, with agriculture being particularly vulnerable. The anticipated increase in drought frequency and severity in future scenarios raises concerns about the feasibility of olive tree cultivation under climate change (2). These forecasts, (3) suggest that, despite the limited water resources expected under warm and dry climate conditions, irrigation could serve as a viable climate change adaptation strategy for cultivators of olive crops. Therefore, proactive adaptation strategies for irrigation are crucial to build resilience and ensure sustainable water management in the face of climate change challenges.

To address the challenges posed by the projected increase in drought frequency and severity in the future, implementing adaptation measures becomes crucial for olive growers. One effective approach is to focus on promoting efficient water use in agricultural practices through the adopting of regulated and sustained deficit irrigation strategies. For sustained deficit irrigation strategy, the irrigation water is applied less than the crop evapotranspiration (ETc) during the whole irrigation season, whilst RDI strategy consists of replacing the crop's evapotranspiration (ETc) requirement at distinct phenological stages, particularly those sensitive to water stress periods such as flowering and oil accumulation, and applying substantially lower irrigation levels than ETc required where stress has no noticeable effect on productivity during the pit hardening phase (4,5).

This involves carefully managing water application to strike a balance between maintaining olive production and ensuring sustainable water management, particularly in the Mediterranean regions marked by a warm and dry summer, with minimal precipitation and notably high evaporation rates (6). In this context, assessing crop water productivity in olive trees under regulated (RDI) and sustained (SDI) deficit irrigation provides valuable insights into the effectiveness of various irrigation strategies, as well as their impact on water use efficiency and olive tree productivity. Armed with these valuable insights, olive growers can make informed decisions and adopt sustainable water management practices for the cultivation of olives. The main objective of this study is to assess water productivity (WP) concerning fruit yield and determine the optimal deficit irrigation strategy that maximizes water productivity in the 'Menara' olive cultivar.

2 Material and methods

The experiment was conducted over two years 2021 and 2022 in the field on 12 years old trees of ‘Menara’ cultivar irrigated with a drip irrigation system and planted with 156 trees/ha density in research station of Saada managed by the National Institute of Agronomic Research in Marrakech, Morocco. The experimental site has Mediterranean climate, which is characterized by semi-arid conditions, hot and dry summers and limited rainfall. The daily irrigation water amounts were estimated by using theFAO-56 approach (7,8). Fruit yield was assessed in seven treatments during 2021 and 2022, focusing on plants subjected to regulated and sustained deficit irrigation. Water productivity was quantified as the ratio between fruit yield (kg/ha) and the amount of water applied (mm) over the entire growing season (9).

The impact of seven irrigation treatment with regard to water productivity was evaluated. In addition to a control regime (FI) fully irrigated: T0 (100% ETc), four water regimes were tested for RDI: T1 (SP 100- NP 70% ETc), T2 (SP 100- NP 60% ETc), T3 (SP 80- NP 70% ETc), T4 (SP 80- NP 60% ETc). We designed the RDI strategy based on knowledge of the sensitivity of the olive tree to water stress across different phenological stages. The irrigation regimes were studied according to the sensitivity of phenological phases to water stress with (SP) 'Sensitive Period' and (NP) 'Normal Period'. The phenological stages were determined annually from 2021 to 2022 according to the BBCH scale (10). For SDI, two water regimes were evaluated: T5 (70% ETc) and T6 (60% ETc), see Table 1.

Table1. Summary of different regulated and sustained deficit irrigation treatments.

Irrigation strategy	Treatment	Irrigation% of ETc by phase	
		Sensitive Period (SP)	Normal Period (NP)
Control	T0	100	100
RDI	T1	100	70
	T2	100	60
	T3	80	70
	T4	80	60
SDI	T5	70	70
	T6	60	60

3 Results and discussion

The results showed that the irrigation treatments used had significant effects on the water productivity (WP) of Menara olive trees, as shown in Table 2. In 2021, the WP showed higher values in the T3 and T4 treatments following the RDI strategy. These treatments demonstrated a notable improvement in WP, ranging from 4% to 18%. Similarly, the T5 and T6 treatments within the SDI strategy demonstrated a remarkable increase in WP, reaching an increase of approximately 25%. In 2022, the treatments following the RDI strategy demonstrated notably higher fruit yield and water productivity. Among these treatments, the RDI strategy exhibited the greatest increase in WP, ranging from 7% to 22% compared to the control T0. However, the SDI strategy with T5 and T6 treatments, which reduced total water application by 30% and 40% throughout the entire season compared to the control T0, recorded the lowest fruit yield and water productivity. Among these treatments, the SDI strategy resulted in the most significant drop in WP, ranging from 19% to 33% compared to T0.

Table 2. Quantity of water applied (mm) in different irrigation treatments during the 2021 and 2022 seasons, along with the percentage variation in water productivity (WP) in terms of fruit yield.

Treatments	Water applied (mm)		Fruit yield (kg/ ha)		% Variation of WP	
	2021	2022	2021	2022	2021	2022
T0	242	279	14165	17846	100	100
T1	218	246	11528	19235	90	122
T2	210	235	10982	17550	89	117
T3	185	212	12808	15538	118	115
T4	177	201	10795	13775	104	107
T5	169	196	12480	8346	126	67
T6	145	168	10655	8705	126	81

The variations in the intensity of water deficit treatments would explain the water productivity responses. Moreover, these results are in accordance with (11) who found that water productivity was significantly greater in trees under no to slight water stress, receiving almost 20% less irrigation to meet the water requirements of the olive trees. In contrast, WP decreased under severe water stress treatments. The decrease in WP under severe stress aligns with the findings reported by (12) in Cobrançosa olive cultivar. In addition, across seasons, (13) reported higher water productivity in RDI treatments in Arbosana olive cultivar. Several studies have suggested an augmentation in water productivity under conditions characterized by moderate stress as noted by (14). These results provide valuable insights into the nature of plant responses to water stress. Over time the SDI strategy, with its limited water availability, leads to a decline in the fruit yield of Menara olive trees. However, the RDI strategy, particularly in the T4 treatment, makes it feasible to conserve a substantial amount of irrigation water, approximately 40% during the phase when pit hardening occurs, and 20% during sensitive periods, all without compromising fruit yield. Many studies recommend for reducing irrigation during the pit hardening period, as it is considered the least sensitive to water water shortage (15). Furthermore, using RDI during this period might result in significant water savings (16). These findings highlight the potential of RDI strategy in enhancing water efficiency and water productivity, offering promising insights for sustainable agricultural practices.

4 Conclusion

Effective and sustainable water management is of utmost importance. In pursuit of this goal, we investigated the efficiency of RDI and SDI strategies, which primarily differ in terms of irrigation timing and the volume of water applied. The findings of the present investigation of two consecutive seasons demonstrated that fruit yield was not severely affected when deficit irrigation was applied during pit hardening. This demonstrates that with the RDI strategy, this period is not too sensitive to moderate water stress, particularly in the T4 treatment, which makes it feasible to conserve a substantial amount of irrigation water, approximately 40% during the phase when pit hardening occurs, and 20% during sensitive periods, all without compromising fruit yield and demonstrated notably higher water productivity.

References

1. A. Ejjiar, F. Arib, The Impact of Climate Change on Economic Growth in Developing Countries Case of Morocco. (2022)
2. L. Tanasijevic, M. Todorovic, L.S. Pereira, C. Pizzigalli, P. Lionello, Impacts of climate change on olive crop evapotranspiration and irrigation requirements in the Mediterranean region. Agric Water Manag. Oct;**144**:54–68. (2014)
3. H. Fraga, J.G. Pinto, J.A. Santos, Olive tree irrigation as a climate change adaptation measure in Alentejo, Portugal. Agric Water Manag. **237**:106193. (2020)
4. R. Gucci, G. Caruso, C. Gennai, S. Esposto, S. Urbani, M. Servili, Fruit growth , yield and oil quality changes induced by de fi cit irrigation at di ff erent stages of olive fruit development. Agric Water Manag. **212**:88–98. (2019)
5. A. Moriana, F. Orgaz, M. Pastor, E. Fereres. Yield responses of a mature olive orchard to water deficits. J Am Soc Hortic Sci. **128**(3):425–31. (2003)

6. S. Er-Raki, A. Chehbouni, S. Khabba, V. Simonneaux, L. Jarlan, A. Ouldbba, et al, Assessment of reference evapotranspiration methods in semi-arid regions: Can weather forecast data be used as alternate of ground meteorological parameters? J Arid Environ. **74**(12):1587–96. (2010)
7. R.G. Allen, L.S. Pereira, D. Raes, M. Smith, FAO Penman–Monteith equation. Crop Evapotranspiration Guidel Comput Crop Water Requir FAO Irrig Drain Pap. **56**:17–28. (1998)
8. R.G. Allen, W.O. Pruitt, J.L. Wright, T.A. Howell, Ventura F, Snyder R, et al, A recommendation on standardized surface resistance for hourly calculation of reference ETo by the FAO56 Penman-Monteith method. Agric Water Manag. **81**(1–2):1–22. (2006)
9. A.A. Fernandes-Silva, J.B. Gouveia, P. Vasconcelos, T.C. Ferreira, F.J. Villalobos, Effect of different irrigation regimes on the quality attributes of monovarietal virgin olive oil from cv. “Cobrançosa”. Grasas Aceites. 30;64(1):41–9. (2013)
10. F. Sanz-Cortés, J. Martinez-Calvo, M.L. Badenes, H. Bleiholder, H. Hack, G. Llácer, et al, Phenological growth stages of olive trees (*Olea europaea*). Ann Appl Biol. **140**(2):151–7. (2002)
11. L.E. Ahumada-Orellana, S.C. Ortega-Farías, P.S. Searles, J.B. Retamales, Yield and Water Productivity Responses to Irrigation Cut-off Strategies after Fruit Set Using Stem Water Potential Thresholds in a Super-High Density Olive Orchard. Front Plant Sci. **21**;8:1280. (2017)
12. A.A. Fernandes-Silva, T.C. Ferreira, C.M. Correia, A.C. Malheiro, F.J. Villalobos, Influence of different irrigation regimes on crop yield and water use efficiency of olive. Plant Soil. **333**(1–2):35–47. (2010)
13. E.R. Trentacoste, F.J. Calderón, O. Contreras-zanessi, W. Galarza, A.P. Banco, C.M. Puertas, Effect of regulated deficit irrigation during the vegetative growth period on shoot elongation and oil yield components in olive hedgerows (cv . Arbosana) pruned annually on alternate sides in San. Irrig Sci. **37**(4):533–46. (2019)
14. F.P. Marra, G. Marino, A. Marchese, T. Caruso, Effects of different irrigation regimes on a super-high-density olive grove cv. “Arbequina”: vegetative growth, productivity and polyphenol content of the oil. Irrig Sci. **34**(4):313–25. (2016)
15. M. Gómez Del Campo, J.M. García, Summer Deficit-Irrigation Strategies in a Hedgerow Olive cv. Arbequina Orchard: Effect on Oil Quality. J Agric Food Chem. **18**;61(37):8899–905. (2013)
16. D.A. Goldhamer. Regulated deficit irrigation for california canning olives. Acta Hortic. **474**:369–72. (1999)