

## IMPACT OF DEFICIT IRRIGATION ON YIELD AND FRUIT QUALITY IN ORANGE (*CITRUS SINENSIS* L. OSBECK, CV. MESKI MALTAISE) IN SOUTHERN TUNISIA

### IMPACT DE L'IRRIGATION DEFICITAIRE SUR LE RENDEMENT ET LA QUALITE DES FRUITS D'ORANGE (*CITRUS SINENSIS* L. OSBECK, CV. MESKI MALTAISE) DANS LE SUD TUNISIEN

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#### ABSTRACT

An experiment on deficit irrigation (DI) was performed in a drip-irrigated orange orchard (cv. Meski Maltaise) during 2013 and 2014 in farm field situated in Médenine, Tunisia. Four irrigation treatments were applied: FI, which was irrigated at 100% of ET<sub>c</sub> for the whole season; DI75 and DI50, which received 25 and 50% less water than FI. These treatments were compared with a farmer method (FM). Clear differences in soil water depletion (SWD) were observed between different irrigation treatments. Significant differences were found in fruit yield between DIs, FM and FI treatments. There were no significant differences between DI75 and FM treatments. Significant differences appeared in total soluble solids and fruit weight. WP was the highest in DI50 treatment and the lowest in Farmer strategy. FI treatment generated the highest net income and was found to be reasonable in areas with no water shortage. Under water scarcity conditions, DI75 treatment provides promising irrigation strategy for optimizing orange irrigation and increasing water productivity, allowing water savings up to 25% with some reduction in yield and net income. The results would be helpful in adopting deficit irrigation in ways that enhance net financial returns.

#### RÉSUMÉ

Une expérience sur l'irrigation déficitaire (DI) a été réalisée dans un verger d'orange (cv. Meski Maltaise) irrigué au goutte à goutte en 2013 et 2014 dans une ferme située à Médenine, Tunisie. Quatre traitements irrigation ont été appliqués: FI consiste à satisfaire les besoins de l'arbre par des apports à 100% de l'ET<sub>c</sub>; DI75 et DI50 ont reçu 25 et 50% moins d'eau que FI. Ces traitements ont été comparés avec la méthode de fermier (FM). Des différences marquées dans l'épuisement de l'eau du sol (SWD) ont été observées entre les différents traitements. Des différences significatives ont été observées dans le rendement en fruits entre les traitements DI, FM et FI, mais ils ne le sont pas entre les traitements DI75 et FM. Des différences significatives sont apparues dans les solides solubles totales et le poids des fruits. La WP était la plus élevée avec le traitement DI50 et la plus basse avec la FM. Le traitement FI généré le revenu net le plus élevé et a été jugé raisonnable pour la conduite d'irrigation du verger d'orange. Le traitement DI75 constitue une stratégie d'irrigation prometteuse pour l'optimisation de l'irrigation des orangers et l'augmentation de la productivité de l'eau, ce qui permet des économies d'eau jusqu'à 25% avec une certaine réduction du rendement et du bénéfice net. Les résultats seraient utiles dans l'adoption de l'irrigation déficitaire de manière à améliorer les revenus nets.

Keywords: orange ; deficit irrigation ; drip irrigation ; yield ; water productivity ; net income ; arid

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## 1. Introduction

Water shortage is the most important factor constraining agricultural production in Tunisia. Presently, there is an increasing pressure to use saline water to intensify agriculture, particularly in the arid part of the country where the demand for more income and employment is high among the rural population. Irrigation of a wide range of relatively new crops is expanding around private shallow wells having a TDS more than 1 g/l. However, the lack of drainage systems in most of the irrigated lands, and the resulting accumulation of salts in the root zone are seriously compromising the sustainability of irrigated farming in arid regions.

Better management of water application is required for farmers seeking a viable mean to maximize water use and reduce the risk of soil salinization. Therefore, effective irrigation scheduling and the use of modern irrigation systems are two possible options to improve water productivity and reduce salt input to soils in arid regions.

Reports by Ayers et al. (1986) and Fereres et al. (1985) show that saline water can be efficiently used through drip irrigation and it results in considerable water saving thus reducing the risks of salinization if the correct management procedures are applied. However the high efficiency of drip system is not always used properly due to inadequate scheduling. The second way to address the issue of water shortage is through the development of new irrigation scheduling techniques such as full irrigation and deficit irrigation, which are not necessarily based on full crop water requirement. Deficit irrigation (DI) is a valuable and sustainable production strategy for dry regions (Geerts and Raes 2009). It is one way of the maximizing water use efficiency for higher yields per unit of irrigation water applied (Fereres and Soriano 2007).

As a choice, deficit irrigation (DI) is particularly important for orchards which are frequently subject to chronic water shortages during the dry season for many successive years. Orchards represent also an important part of the irrigated sector and are usually using the highest share of irrigation water. For instance, in Tunisia fruit trees cover about 40% of irrigated lands and represent an important component of the productive farming system in the country. However productivity is usually low and irrigation with waters having more than 1.5 g/l of TDS is commonly practiced without provision of drainage. Due to chronic water shortage and soil degradation hazards in irrigated orchards, there is a need to develop strategies that may help to save water and control salinity. In the absence of drainage systems and under conditions of high evaporative demand and chronic shortages of water, techniques based on irrigation restrictions seem to be reasonably appropriate. The present work examined the response of yield and fruit quality of orange trees to DIs applied over two consecutive years to define the best irrigation programme based on deficit irrigation with saline water of orange trees adapted to the arid conditions of Tunisia.

## 2. Materials and methods

This study was conducted in a commercial orchard of mature orange trees (*Citrus sinensis*, L. Osbeck, cv. Meski Maltaise) grafted on Bigaradier rootstocks, in Southern Tunisia (33° 19'N, 10° 27' E). Trees were planted 12 years ago, spaced 7 m x 6 m, and were irrigated with drip line with four drippers per tree (4 l/h), 1 m apart, using irrigation waters of about 1.5 g/l of TDS. The soil is a sandy loam with 62% sand, 29% silt, and 9% clay. The field capacity and permanent wilting point are 17 and 9.2%, respectively, and bulk density was 1.41 g/cm<sup>3</sup>. The total soil available water for an assumed orange root extracting depth of 0.80 m, was 88 mm. The climate is typical of arid areas with an average annual precipitation of 150 mm and annual Reference evapotranspiration (ET<sub>o</sub>-PM) is about 1450 mm.

Four irrigation treatments were applied: full treatment (F1) irrigated during the watering season to provide trees with their full water requirement based on ET<sub>c</sub> calculations. Deficit treatments irrigated with irrigation water quantities that cover 75% and 50% of ET<sub>c</sub> (DI75 and DI50) and FM irrigated according to farmer irrigation practice. Water meters were used to measure the volume of irrigation water applied in each treatment.

Application developed on Excel for managing irrigation of fruit trees was used to determine water and irrigation requirements. This application requires data on reference evapotranspiration (ET<sub>o</sub>), crop coefficient (K<sub>c</sub>), deficit coefficient (K<sub>d</sub>), rainfall and growth stage lengths.

The FM, DIs and full treatments were implemented from early May to the end-December. Irrigation treatments were scheduled weekly because irrigation of orange adopted by farmers at the study area is on weekly basis. Therefore, an irrigation frequency once week was adopted using different amounts of water across different treatments.

Nutrient supply was applied according to the levels of fertilizer used by farmers for orange production in study area, being 200-100-150 kg/ha of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O, respectively.

For both years, soil water content was monitored by gravimetric method to determine the soil water depletion. Soil salinity was also monitored by sampling soil at three sites perpendicular to the drip line and at three sites between the emitters. Conceptually, these should be areas representing the range of salt accumulations (Bresler 1975).

At the end of each season, the yield was determined for each individual control tree by weighing the orange fruits with a digital scales and the irrigation water productivity (IWP) was determined by dividing the yield (kg/ha) for each treatment by the volume of irrigation water applied. Fruit-quality characteristics were analyzed at harvest on 20 fruits per tree including fruit weight, total soluble solids content (TSS) with a thermo-compensated refractometer.

The net income for each treatment was computed by subtracting all the production costs from gross incomes. All calculations were done based on a unit area of 1ha. Production costs include fertilizer, insecticide, irrigation system and harvesting costs. Gross return was calculated by multiplying the total amount of product by its market price.

## 3. Results and discussion

The average E<sub>ce</sub> values under the different irrigation treatments are presented in Figure 1. Initial soil salinity values determined early May were, respectively, 2.5 and 2.9 dS/m in the first and second year. During both year, E<sub>ce</sub> values measured at harvest were lower compared to initial E<sub>ce</sub> values in all irrigation treatments. This was an indication of leaching of soluble salts by fall, spring and winter rains (52 and 59 mm). Figure 1 shows a decrease in E<sub>ce</sub> values for FI treatment. Higher E<sub>ce</sub> values have been observed for the second year due to the higher initial E<sub>ce</sub>. FM and DI75 treatments resulted also in low E<sub>ce</sub> values at harvest without significant difference ( $p < 0.05$ ) with FI. However, higher soil salinity levels were observed for DI50. Kaman et al. (2006) reported that deficit irrigation may contribute to greater risk of increased soil salinity due to reduced leaching. E<sub>ce</sub> values under the different treatments were generally lower than the E<sub>ciw</sub> used. Singh and Bhumbra (1968) reported that in soils containing less than 10% clay the E<sub>ce</sub> values remain lower than E<sub>ciw</sub>. Low values of E<sub>ce</sub> under the current climatic conditions were also due to the natural leaching of soluble salts by rainfall events.

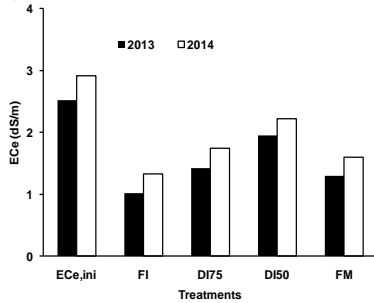


Figure 1. Soil salinity (E<sub>ce</sub>, dS/m) under different irrigation treatments.

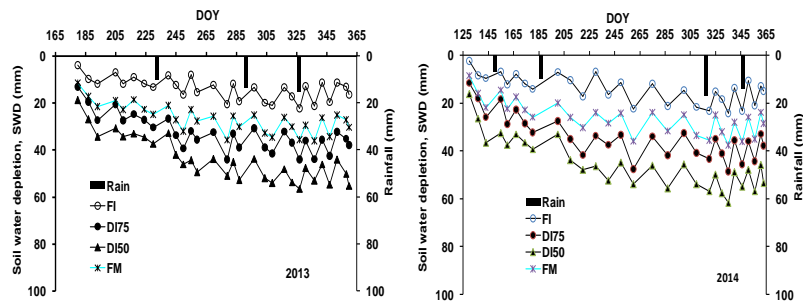


Figure 2. Soil water depletion (SWD, mm) for each treatment of orange in 2013 and 2014.

The soil water depletion (SWD) variation indicated clear differences in SWD between different irrigation treatments according to irrigation rates (Figure 2). Full treatment (FI) had lower values of SWD indicating that the soil water content was maintained at field capacity than the other treatments. For DI75, DI50 and FM treatments, soil water depletion decreased gradually with time. This decrease was always more accentuated in DI50 than in DI75 and FM treatments. The soil water depletion levels in the Farmer treatment remained lower as compared to that in DI75 and DI50.

Figure 3 record the yield and fruit-quality parameters during the study years. The results showed significant differences between treatments for fruit weight and TSS. Water stress caused a significant drop in the fruit weight and an increase in total soluble solids. Yakushiji et al. (1998) showed that water stress leads to an increase in TSS, not a result of dehydration of the fruit, but rather a result of the osmoregulatory response caused by the lack of water (Hockema and Etxeberria, 2001). Moreover, fruit yield show statistically significant differences between DIs and FI. The observed differences were appreciable and the changes in all these parameters were related to the water deficit undergone by the trees in each treatment. Thus, conditions causing different levels of water stress in orange trees, will have significant effect on the yield, and also affect other properties which have direct relevance on the final quality of the harvested product. These results are in disagreement with those of Vélez et al. (2007) who mentioned no significant differences in final production, fruit weight and number of fruits per tree, in response to a DI strategy of cultivation in “Clementine of Nules”.

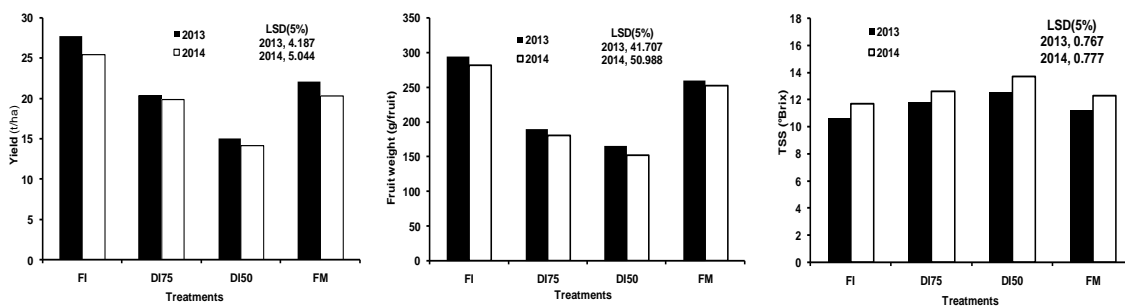


Figure 3. Yield and fruit quality under irrigation strategies for the study period.

In terms of water savings, the FM, DI75 and DI50 reduced irrigation water supply between 578-3620 and 960-3540 m<sup>3</sup>/ha, respectively, in 2013 and 2014 with different yields in comparison to FI treatment (Table 1). With farmers irrigation strategy less water was applied (654 and 608 mm) than that in FI. Irrigation water productivity (IWP) ranged from 4.31 to 3.44 kg/m<sup>3</sup> for DI50 and FM, respectively. The highest IWP values were observed in DI50 treatment; whereas the lowest IWP was obtained under FM due to more applied irrigation water. Increasing IWP may be a means of achieving efficient water use. Climatic conditions in arid areas of southern Tunisia, where available water for irrigated land is the most limiting factor, will force farmers to improve water-use efficiency to maintain profitable yields with less water. Strategies such as DI have shown that water productivity can be enhanced (Ali et al., 2007) and could be associated with acceptable commercial production. Thus, the application of deficit irrigation with water restriction of 25% provides promising irrigation strategy for optimizing orange irrigation and increasing water productivity for orange orchards, with some yield reduction.

Table 1. Irrigation supplies, water saving and productivity (kg/m<sup>3</sup>) under different strategies

Treatments	Irrigation (mm)		Water saving (m <sup>3</sup> /ha)		IWP (kg/m <sup>3</sup> )	
	2013	2014	2013	2014	2013	2014
FI	711	704	-	-	3.60	3.51
DI75	530	522	1810	1820	3.87	3.77
DI50	349	341	3620	3540	4.31	4.06
FM	654	607	578	960	3.48	3.44
LSD (5%)	-	-	-	-	0.413	0.281

Economic analysis was done by using averages of 2 years (Figure 4). The results show that the highest net income was observed with FI treatment followed by FM and DI75 treatments, whereas DI50 treatment showed the lowest net return. High values of net income under FI were due to enhanced yields as compared with other treatments. Net income values decreased from FI to DI50 treatment, and FI was found to be the most profitable. The greatest net income produced by FI treatment is recommended in orange production with no water scarcity. Moderate DI75 resulted in a better net income and can be applied in 'orange' orchards allowing water savings up to 25% with some reduction in yield and net income. This supports the more widespread adoption of DI75 strategies for orange growers in the region.

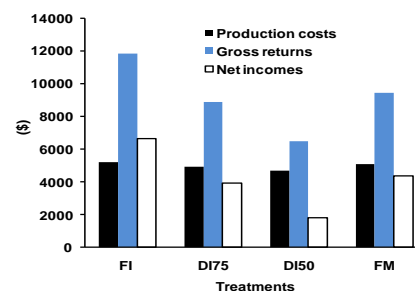


Figure 4. Production costs and net return of orange production under different treatments

#### 4. Conclusion

This study showed that irrigation amounts applied under FM in orange orchards was lower than actually needed. While recommended irrigation requirement is 100% of ET<sub>c</sub>, farmers used 8-13.7% less water indicating that farmer practices a form of unintended DI. When DI was applied using 25% less water than FI, orange yield was significantly reduced. There were no significant differences between DI75 and FM treatments with 14-19% less irrigation water than FM used in DI75. DI50 treatment caused significant decrease in orange yield with a reduction in size and weight. TSS was higher in the deficit treatments and especially in the most restrictive treatment DI50. While the lowest IWP was recorded under FM treatment, the IWP under DI75 or DI50 treatment was comparatively higher than FI treatment. The DI50 significantly reduced the net income compared to FI treatment. DI75 resulted in a better economic return. Consequently, moderate water restriction (DI75) can be applied as a long-term strategy under water scarcity conditions in commercial 'orange' orchards allowing water savings up to 25% with some reduction in yield and in the economic return.

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