EFFECT OF DEFICIT IRRIGATION ON VEGETATIVE GROWTH AND FRUIT YIELD PARAMETERS OF YOUNG OLIVE TREES (*Olea europaea L.*) IN SEMI ARID AREA OF MOROCCO

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Abstract

Water scarcity has become a challenge for agricultural production in Morocco, particularly in areas characterized by high evaporative demand (about 1500 mm/year), low and irregular rainfall (200-300 mm/year). One of the options that can help to save irrigation water under these conditions is the adoption of deficit irrigation by farmers. However, restriction of applied water may affect negatively the performance of crops. This study aims at evaluating the effect of this technique on vegetative growth and fruit yield parameters of young olive trees. The trial was carried out at Sâada experiment station in Marrakech region. The climate is a typical Mediterranean semi-arid with a hot and dry summer. The olive orchard was planted in December, 2010. The crop was exposed to three watering regimes, FDI=Full drip irrigation corresponding to 100% of full crop water requirements (FWR), DDI: Deficit drip irrigation (70% of FWR) and FU= Flood irrigation using the farmer’s technique. The amounts of irrigation applied to the crop between January and November was, in 2012, 116 mm, 81 mm, and 538 mm for FDI, DDI and FU, respectively. In 2013, they were, respectively for the same treatments, 212 mm, 148mm and 545. The results showed that, for the two years of trials, tree height, trunk perimeter and diameter and canopy volume the difference was significant only between the systems of irrigation (flood vs drip) and not between FDI and DDI. The values of all these parameters were the highest under full and deficit drip irrigation. The effect of watering regime was also significant on the tree fruiting rate measured only in year 2013 and the highest values were obtained with DDI (62%) and FDI (60%) as compared to FU (40%). The effect of water regimes on olive fruit yield in 2013 was significant. The highest yield was recorded with FDI (146kg / ha) which did not differ significantly from that of DDI (117.6 kg / ha); while the lowest value of 64.2 kg/ha was obtained with FU. The variation among the three treatments for olive weight was significant and the values were 3.42 g for FDI, 3.36 g for DDI and 3.38 g for FU. The FDI induced a better olive caliber and high pit weight in comparison with FU. However, the olive water and oil contents were not affected by watering regimes.

Keywords: olive, water stress, deficit irrigation, flood irrigation agronomical parameters

Introduction

In Morocco, water scarcity is one of the main factors limiting agricultural development. Currently and more importantly in the future, irrigated agriculture will suffer more from water shortage, particularly in the areas that are characterized by high evaporative demand (about 1500 mm/year), low and irregular rainfall (200-300 mm/year), and repeated periods of
droughts. Under these conditions, irrigation management strategy has to shift from maximizing the yield per unit area or land productivity to maximizing the productivity per unit of water used by the crop or water productivity. However, the land productivity should be maintained at the optimal level.

Olive (*Olea europaea* L.) is among fruit trees known for their high dietetic, economic and social impacts in our country and this has led to an important increase in new olive plantings under irrigation in many regions of the country. However, large new orchards are still irrigated by a traditional inefficient surface irrigation system which leads to high water losses (more than 65% of agricultural water). Furthermore, irrigation water is scarce and expensive. Thus, deficit irrigation, scientifically proven to be more efficient can be an alternative in Morocco. However, before generalizing the application of this technique on young olive trees grown, more information on its effect on the agronomical performances of the crop is needed.

**Material and methods**

The experiment was conducted for two years 2012 and 2013 in a three years old olive orchard (*Olea europaea* L. cv Menara) installed in 2010 at Sâada Experiment Station of INRA Marrakech. The climate in this region is a typical Mediterranean semi-arid characterized by hot and dry summer. Annual rainfall in 2012 and 2013 was 153.7mm and 186.2mm, respectively. The soil is of a loamy clay texture and it is over 2 m deep.

Three watering regimes were studied: FDI= Full drip irrigation (100% of crop water requirement or ETc); DDI= Deficit drip irrigation (70% of ETc); FU=Flood irrigation (farmer’s technique).

During the first year after planting, all trees were irrigated equally to guarantee the uniformity of plant development and avoid seedlings mortality. In the second year, irrigation water was applied based on the estimation of tree evapotranspiration (ETc). The ETc was calculated using the equation: \( ETc = ET_0 \times Kc \times Kr / Ne \). Where ET0 is the reference evapotranspiration, Kc is the crop coefficient for olive tree, Kr is the coefficient to correct for incomplete cover and Ne is the efficiency of irrigation network.

A randomized complete-block design was used with three replications of 21 trees each. The spacing between trees was 8 m x 8 m.

The parameters studied are follows:

Vegetative growth was assessed arrounding 2012 and 2013 by measuring plant height and trunk perimeter and diameter for all trees in each treatment and block. The canopy volume (CV) was also calculated according to the equation: \( CV = 2/3\pi r^2H = 2/3\pi D^2/4H = 0.536 \times (D)^2 \times H \); where 

\( H \) is the tree height, 

\( D_1 \) and \( D_2 \) are transversal diameters and 

\( D = (D_1+D_2)/2 \).

The fruit and oil measurements were performed since the trees started producing olives in 2013 and are related to fruiting rate, fruit weight and oil content parameters.

Data were statistically analyzed using the analysis of variance and mean comparisons were performed using the Student–Newman & Keuls test when the treatment effect is significant.

**Results and discussion**

**Tree height:** During the two growing seasons, 2011-12 and 2012-13, the average tree height varied depending on the watering regimes (Table 3); but DDI did not differ significantly from FDI. In the second year, the high mean value of this parameter was 255.2
cm under FDI which was not significantly different from that of DDI (248.3 cm). The height growth obtained with FDI (15.4%), followed by DDI (12.2%) and then FU (10.7%).

**Trunk perimeter:** For the two years of the experiment, the trunk perimeter varied significantly according to watering regimes (Table 3). The high mean values of this parameter were obtained with the DDI with 19.4 cm and 21.4 cm for the first and second years, respectively which did not differ significantly from values recorded in the case of FDI. However this growth rate of the trunk perimeter was reduced by 50% under FU watering regime.

Table 3: Tree high and trunk perimeter of young olive trees measured under different watering regimes (E.S= Error Standard).

<table>
<thead>
<tr>
<th>Watering regimes</th>
<th>2012 Mean ± E.S</th>
<th>2013 Mean ± E.S</th>
<th>Growth rate (%)</th>
<th>2012 Mean ± E.S</th>
<th>2013 Mean ± E.S</th>
<th>Growth rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI</td>
<td>215.8 ± 17.7 a</td>
<td>255.2 ± 19.3 a</td>
<td>15.4 a</td>
<td>18.9 ± 3.1 a</td>
<td>20.4 ± 3.7 a</td>
<td>7.4 a</td>
</tr>
<tr>
<td>DDI</td>
<td>217.9 ± 15.5 a</td>
<td>248.3 ± 18.4 a</td>
<td>12.2 a</td>
<td>19.9 ± 3.3 a</td>
<td>21.4 ± 2.8 a</td>
<td>7.0 a</td>
</tr>
<tr>
<td>FU</td>
<td>186.7 ± 17.7 b</td>
<td>209.1 ± 17.6 b</td>
<td>10.7 b</td>
<td>16.5 ± 5.3 b</td>
<td>17.1 ± 5.0 b</td>
<td>3.6 b</td>
</tr>
</tbody>
</table>

Values with the same letter do not differ significantly between the irrigation regimes (P > 0.05)

**Trunk diameter:** A significant variation of trunk diameter was shown under the watering regime (Table 4). For the two years, high values of this parameter were obtained under FDI and DDI. Low values were shown in FU with 107.8 cm and 141.8 cm for the first and second year respectively.

**Canopy volume:** This parameter varied significantly according to the watering regimes for the two years of the experiment (Table 4) and the high average values were obtained with FDI and by DDI and did not differ significantly. The low values of this parameter were obtained with FU (1.07 m³) and (2.25 m³) for the first and second years, respectively.

Table 4: Trunk diameter and canopy volume of young olive trees measured under different watering regimes (E.S= Error Standard).

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<th>Growth rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI</td>
<td>137.2 ±21.1 a</td>
<td>178.5 ±26.4 a</td>
<td>23.1 a</td>
<td>1.37 ± 0.08 a</td>
<td>4.3 ±0.07 a</td>
<td>68.5 a</td>
</tr>
<tr>
<td>DDI</td>
<td>133.9 ±19.1 a</td>
<td>174.2 ±27.9 a</td>
<td>23.1 a</td>
<td>1.33 ± 0.08 a</td>
<td>4.0 ±0.07 a</td>
<td>67.1 a</td>
</tr>
<tr>
<td>FU</td>
<td>107.8 ±15.7 b</td>
<td>141.8 ±14.4 b</td>
<td>23.9 a</td>
<td>1.07 ± 0.09 b</td>
<td>2.2 ±0.03 b</td>
<td>52.4 b</td>
</tr>
</tbody>
</table>

Values with the same letter do not differ significantly between the irrigation regimes (P > 0.05)

**Fruiting rate:** The effect of varying the watering regime on the fruiting rate of young olive trees measured only in 2013 was significant (P<0.001). The high value of this parameter was obtained with DDI (62%) which was slightly higher, but not significantly, than that of FDI (60%) (Figure 1). Only 40% of young trees produced olive fruits under FU watering regime.
Olive fruit yield: Data collected in 2013 on olive fruit yields showed that this parameter was significantly affected by the variation of the irrigation treatments (P= 0.03) (Figure 2). The highest yields were recorded under FDI (146 kg / ha) and DDI (117.6 kg / ha) regimes and were significantly higher than the one obtained with FU (64.2 kg / ha).

Olive weight: Significant variation was shown among the three watering regimes (P=0.003) (Table 4). Average olive weight was higher under FDI (3.42 g) compared to FU (3.38 g). The values of this parameter obtained by latter watering regime did not differ significantly from those recorded in the case of DDI (3.36 g).

Olive dimensions and Pit weight
FDI had induced a better olive caliber with high values of fruit width and length and high pit weight in comparison with FU which gave low values for these parameters (Table 4). However, the variations shown among the three watering regimes for these parameters were not significant.

Water and oil content: The high values of water content were obtained under DDI (18.6%) (Table 4). High values of oil content were obtained under FU (9.6%) and low values were obtained with FDI (8.3%). However, variations of water and oil content shown among the three watering regimes were not significant.
Table 5: Olive fruit and oil characteristics under three irrigation regimes

<table>
<thead>
<tr>
<th>Irrigation regimes</th>
<th>Olive fruit characteristics</th>
<th>Olive oil characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Olive weight (g)</td>
<td>Fruit Width (mm)</td>
</tr>
<tr>
<td>FDI</td>
<td>3.42 a</td>
<td>16.9</td>
</tr>
<tr>
<td>DDI</td>
<td>3.38 b</td>
<td>16.3</td>
</tr>
<tr>
<td>FU</td>
<td>2.36 b</td>
<td>15.4</td>
</tr>
</tbody>
</table>

Values with the same letter do not differ significantly (P > 0.05)

Discussion

Water scarcity is one of the main factors limiting olive production in dry areas of semi-arid regions. For this reason it is necessarily to reduce water use in irrigation and thereby increase crop water use efficiency. Deficit irrigation is one of the strategies proposed many years ago to improve water productivity and reduce the irrigation water application (Ruiz-Sanchez, 2010). In a broad sense, and according to English and Raja (1996), deficit irrigation consists of the deliberate and systematic under-irrigation of crops. In other words, the amount of water applied is lower than that needed to satisfy the full crop water requirements.

The vegetative growth of woody trees is recognized as being the most sensitive process to deficit irrigation (Ruiz-Sanchez et al., 2010). In our experiment, the tree height was not affected by deficit irrigation (DDI) in comparison with full irrigation (FDI). The olive trees responded positively to irrigation, even with low amounts of water (Fernández and Moreno, 1999). However, we noted a decline in this parameter under flood irrigation (Farmer’s Use technique) where the period between irrigations was very long (around one month) and this exposed the young olive trees to water stress.

Trunk perimeter and diameter were not reduced by the application of DDI as compared to FDI; but they were negatively affected by FU. Generally, the reduction of the trunk perimeter is mainly due to the negative influence of water deficit, induced by FU treatment in our case, on the restriction of the physiological and biochemical processes (Ennajah, 2006). The reduction of the trunk diameter of the young trees under the influence of water stress was reported by Fereres (1984). These reductions in shoot elongation and trunk cross sectional area in response to water deficits lead to reductions in tree size and smaller canopies (Pérez-Pastor et al., 2009), things that we observed in our experiment under FU regime. In fact, canopy volume was reduced under FU watering regime; but it was not affected under DDI. Furthermore, olive production during the first few years depends on how the canopy covers the hedgerow to intercept maximum radiation (Gomez-del-Campo, 2010). Our results showed that DDI allowed an early entry in production with a rate of fruiting high in comparison with the two other watering regimes. Compared with other fruit crops, olive is characterized by a long unproductive period. Thus, appropriate management of the crop during the years following planting reduces the period between tree planting and fruit setting and this was observed in our study with the application of deficit irrigation.

The highest values of olive fruit yields were recorded under FDI condition and they were not significantly different from those recorded in DDI plots. In contrast low olive yield was obtained by FU indicating that this watering regime is inefficient. Previous studies showed that the increased production of olives is based on the water use efficiency (Michelakis, 1998) which strongly depends on soil moisture during sensitive phenological stages (Mennah et al., 2012). The fruit weight is significantly decreased under DDI and FU compared to FDI. These findings confirm results previously published by D’Andria et al. (2009) who also found that irrigation increases fruit number. But, in our case, fruit olive dimensions and fruit water...
accumulation were not affected by watering regimes variation; although Girona et al., (2004) reported that the latter parameter is highly sensitive to the level of water deficit during all fruit developmental stages; whereas dry matter accumulation is relatively insensitive. No differences in oil content were found between the three watering regimes. Our results agree with those of Lavee and Wodner (1991), who reported that the application of irrigation usually causes an increase in fruit and oil yields and a decrease in oil content. However, in others studies, no differences in oil content, expressed as % of fresh or dry weight, were found when different irrigation regimes were supplied.

In conclusion the application of DDI frequently (each 2 days in this case) kept the soil relatively wet in the root zone and hence did not affect significantly most of the agronomical parameters measured on young olive trees. Consequently, it did not induce a water stress in comparison with FDI. In addition, it allowed an early entry in fruit production with a higher rate of fruiting in comparison with the two other watering regimes. The fruit yield under DDI did not differ significantly from that obtained under FDI and it was 80% higher than that obtained under FU conditions. DDI permits also 30% of water saving compared to FDI and more than 70% when compared to FU. This latter regime leads to a water stress with low water use efficiency despite the high amount of irrigation water applied.

References


