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# The effect of predetermined deficit irrigation on the performance of cv. Muhasan olives (*Olea europaea* L.) in the eastern coastal plain of Israel

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**Abstract**

The response of cv. Muhasan trees and its fruit characteristics to a 50% regulated deficit irrigation (RDI) was studied. The general response to the reduced irrigation was relatively small. However, the schedule of water application was very significant for various fruit characteristics. In the best schedule the 50% reduction in annual irrigation water reduced the oil yield over 4 years by only 12.2% and that of the fruit yield by 18.5%. The most efficient schedule was based on applying all the irrigation water after stone hardening. In lighter soils however, with lower water holding capacity or in regions with a lower rainfall diverting some of the water to the pre-bloom and fruit set period might be needed. The fruit mesocarp/endocarp (flesh/pit) ratio was dependent on the water availability during the stone hardening period. This ratio was significantly improved when water availability during the stone hardening period was reduced. The rate of oil accumulation was also affected by the irrigation schedule but was about the same in 'on' and 'off' years. Fruit growth was less affected by the irrigation schedule but most significantly by the yield load. All the affects of the irrigation schedules were more expressed in the 'on' years than in the 'off' years. No clear cut differences or consistent effects of the irrigation schedule were found on the degree of alternant bearing and mineral content of the leaves.


*Keywords:* Olive; Deficit irrigation; Oil accumulation; Fruit growth; Alternate bearing

## 1. Introduction

The world olive industry in the past and to a large extent is still based on dry-land farming. Intensification and irrigation was first applied to table olives on a commercial scale about 150 years ago (Hendrickson and Veihmeyer, 1949). During the last 40–50 years this approach is slowly being adopted also in the olive oil sector (Samish and Spiegel, 1961; Lavee, 1992, 1994). Application of irrigation caused in all cases enhanced vegetative growth, increased fruit and oil yields but a reduction of the relative oil content in the fruit's mesocarp (Spiegel, 1955; Lavee and Wodner, 1991; Inglese et al., 1996). Lately, some workers (Costagli et al., 2003; Moriana et al., 2003) indicated that the oil content in the mesocarp was not decreased, this is true in all cases for the total oil content in the fruit but only rarely, due to the degree of stress, also on the relative oil content. Generally however, although the total oil production per hectare was markedly increased the relative efficiency of oil accumulation in the fruit is usually slightly reduced. The degree of reduction in the relative oil content due to irrigation is highly cultivar dependent. All the various irrigation systems used caused a relative oil reduction in the fruits. However, the water quantity applied has also a significant indirect affect on oil accumulation. The balance between an increase in fruit yield and the relative reduction of the oil content in the fruits is critical for the economic oil production (Samish and Spiegel, 1961). In Israel a wide range of oil and dual purpose cultivars, local and introduced, were tested for their oil production efficiency under intensive irrigated conditions. These tests led on one hand to further irrigation studies and on the other to breeding programs of new cultivars responsive to for intensive

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growing conditions required for an efficient and high oil producing industry (Lavee, 1994). Goldhamer et al. (1994) quantified the relationship between water application and orchard feasibility under the conditions in California.

Cv. Muhasan which is grown on a wide scale in Israel, Palestine and Jordan under both irrigated and dry-land conditions is one of the cultivars showing a most significant reduction in the relative oil content due to irrigation (Lavee and Wodner, 1991). Intensification including irrigation is critical for elevating the traditional olive industry to the economical level required today. Although the increase in fruit production of cv. Muhasan due to irrigation is considerable, the relative reduction of the oil content in the fruit of this cultivar is most significant and has critical implications on the processing cost and procedures in the oil mill. Furthermore, the scarceness and high cost of water in many Mediterranean olive growing regions requires a careful determination of the optimal economical impact of any amount of water applied (Moriana et al., 2003; Orgaz and Fereres, 1997). This is of particular importance as although yield increase is linearly related to the level of transpiration while the effect of added irrigation water is in many cases not (Lavee et al., 1990; Pastor et al., 1999). In various regions where suitable land is available the amount of utilizable water is restricted. Thus, the effectiveness and economic value of each cubic meter of water used in complimentary versus full irrigation systems has to be evaluated.

The need for quantifying the efficiency of water application by using regulated deficit irrigation (RDI) as developed for various crops (Fereres and Goldhamer, 1990) was suggested also for olives (Goldhamer et al., 1994; Pastor and Orgaz, 1994). In California, Goldhamer (1999) reported that reducing the optimal irrigation requirement of olive trees in the summer by 25% did not reduce the final fruit yield. Furthermore, Girona et al. (2002) showed that the crop coefficient ($K_c$) for the oil yield is considerably lower than the optimal $K_c$ for the vegetative growth of the trees. The amount of water commercially utilized in full irrigated olive orchards in the coastal plain of Israel with an average of 450 mm of rain was determined on basis of water consumption at a mean fruit production to be 5000–6000 $m^3$/ha. Initial studies on the effect of deficit water application even in an old traditional orchard had a marked effect on fruit and total oil production. A single relatively late mid-summer water application of 800 $m^3$/ha was enough to double its oil yield (Lavee et al., 1990). Under such conditions, using an old (about 60-years-old) traditional cv. Souri orchard additional earlier water applications were ineffective. Similarly Patumi et al. (1999) showed a marked increase in fruit and oil production due to irrigation but without a clear difference between water application within the range of 2500–7500 $m^3$/ha.

In the present study, the effect of a uniform deficit water supply applied to young, 5-year-old, bearing olive trees was determined. Different irrigation schedules of the same amount of water per season were tested. The water application in the various treatments was based on physiological stages of the fruit and tree development. Fruit and oil yields, time of maturation, the effect on various fruit characteristics and alternate bearing were determined.

## 2. Materials and methods

A 5-year-old cv. Muhasan orchard at the foot hills between the Judea Mountains and the Coastal Plain in the center of Israel with planting distances of 4 m × 7 m was chosen for the study. The soil at the experimental site is a rather uniform sandy loam with a rather high water holding capacity. The pan evaporation in that region reaches at the peak in mid-summer about 7 mm/day. The regional mean rain fall (in winter only) is in the order of 450 mm/annum. At commercial intensive cultivated olive orchards with full irrigation, the peak water application in August 30–40 $m^3$/day/ha is depending on the level of production. The total annual water application ranges between 5500 and 6000 $m^3$/ha. In the present study, a pre-determined deficit amount water (2600–2700 $m^3$) was applied according to different irrigation schedules. A drip irrigation system based on a single dripper line per tree row with 4 l drippers 1 m apart was used. Seven different irrigation schedules with the deficit amount of water as well as a full irrigation and a dry treatment were applied. The water application was bases in all treatments and throughout the season on a single weekly irrigation when applied. The amount of water applied was regulated by the length of the irrigation period. The irrigation period started in each of five consecutive years in mid-April and ended by the third week of December. The irrigation schedule and weekly amount of water applied to each of the treatments is shown in Table 1.

Table 1
The irrigation schedule and water quantities used in the deficit irrigation trial with cv. Muhasan olives at the inner coastal plain of Israel

| Week no. | Dates | Irrigations | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1–2 | April 14–21 | 2 | 140 | 70 | 70 | 70 | 0 | 0 | 70 | 140 | 0 |
| 3–4 | April 28–May 5 | 2 | 140 | 70 | 70 | 70 | 0 | 0 | 140 | 140 | 0 |
| 5–8 | May 12–June 2 | 4 | 140 | 70 | 140 | 150 | 0 | 0 | 140 | 140 | 0 |
| 9–14 | June 9–July 14 | 6 | 140 | 70 | 0 | 0 | 0 | 140 | 0 | 70 | 0 |
| 15–23 | July 21–September 15 | 9 | 200 | 80 | 200 | 140 | 200 | 140 | 80 | 80 | 0 |
| 24–26 | September 22–October 6 | 3 | 140 | 80 | 0 | 0 | 200 | 0 | 80 | 80 | 0 |
| 27–28 | October 13–October 20 | 2 | 140 | 80 | 0 | 0 | 140 | 0 | 80 | 80 | 0 |
| 29–33 | October 27–November 24 | 5 | 140 | 70 | 0 | 70 | 0 | 70 | 70 | 0 | 0 |
| 34–36 | December 1–December 15 | 3 | 70 | 70 | 0 | 70 | 0 | 70 | 70 | 0 | 0 |
| Total ($m^3$/ha) | April 14–December 15 | 36 | 5370 | 2660 | 2640 | 2660 | 2680 | 2660 | 2660 | 2660 | 0 |

The illustrated irrigation program was run for five consecutive years, from mid-April to mid-December. The numbers represent weekly water applications in $mm^3$/ha.
T: Treatment.