Effect of Deficit Irrigation on Lemon Water Requirements and Yield in the Jordan Valley*

Shatanawi M.R.**, A. A. Suleiman**, and J. Al-Bakri**

ABSTRACT

In countries with limited water resources like Jordan; deficit irrigation (DI) could be used as a strategy to manage water more efficiently without significant yield reduction. This research was conducted in the Jordan Valley to assess the impact of two DI levels on lemon water requirements and productivity. The study was conducted for three consecutive years (2005, 2006 and 2007) on full-grown lemon trees using three irrigation treatments: T1 represents 100% of crop evapotranspiration (ET); T2 for 75% of T1; and T3 for only 50% of T1. The root zone depletion analysis showed that lemon trees in T3 were under water stress from early June to harvest and from mid of June to end of October for T2 in the three years, whereas no water stress occurred for T1 in the different years. The yield for the 75% treatment was 26.8, 17.8 and 22.0 tons/hectares for the three years, respectively. The water saving for T2 and T3 was 18-19 and 37-39%, respectively. Improved but not significant water use efficiency and economic water productivity were observed for T2 and T3 in the three years. The implementation of the 75% DI would be recommended to save water while sustaining the yield. The results of this research could be scaled up to demonstration level, and further be disseminated to the citrus growers’ community in the Jordan Valley.

Keywords: Deficit Irrigation, Lemon, Jordan Valley.

INTRODUCTION

Jordan is considered one of the ten poorest countries worldwide in water resources. Due to limited water resources and the relatively high population growth rate (2.5% in 2004), the annual per capita share is expected to decrease from 160 m³ in recent years to less than 90 m³ by 2025 (Shatanawi et al, 2007). The irrigation share of the total water uses demonstrates significant decrease during the period 1985-2005 (78% in 1985 to 62% in the year 2005). In absolute figures, irrigation water use has also been reduced from its peak in 1993 (726 MCM/a) to 511 MCM in the year 2003 (MWI-GTZ, 2004).

The scope for further irrigation development to meet food requirements in the future is severely constrained by the decreasing water resources and the growing competition among the different sectors for water. Therefore, reducing the irrigation water without significantly affecting crop production will result in releasing resources for other uses or expanding the irrigated area. In the context of improving water productivity, there is a growing interest in deficit irrigation (DI); an irrigation practice whereby water supply is reduced below maximum levels and mild stress...
is allowed with minimal effects on yield (Demir et al., 2006). The use of DI for fruit trees might not be harmful and might even enhance yield (Lampinen et al., 2001; Shatanawi et al., 2003) and reduce tree canopy size while improving fruit density (Goldhamer et al., 2006). The principles underlying DI can be viewed as an optimizing strategy under which crops are deliberately allowed to sustain some degree of water deficit and yield reduction (English, 1990; Silber et al., 2006). Under conditions of scarce water supply and drought, deficit irrigation can lead to greater economic gains than maximizing yields per unit of water for a given crop (FAO, 2002).

Deficit irrigation can be either sustained or regulated. The former is practiced during the whole season while the latter is carried out during the non-critical phonological crop stages, particularly in summer (Girona et al., 2006). According to Castel and Buj (1990), the regular deficit irrigation (RDI) reduced the yield of orange trees by 5 to 15% and increased the total soluble solids and acid contents of the fruit juice. The differences in yield were mainly attributed to the effect of the RDI on average fruit weight. Germanà and Sardo (2004) indicated that the increased fruit weight and the incremental water savings could compensate the reduction in yield under deficit irrigation. Domingo et al. (1996) indicated that RDI could reduce leaf water potential of lemon trees and decrease the relative fruit growth rate. However, chemical characteristics of the lemon fruit were not significantly modified by the RDI treatment.

Water saving was seen as the big advantage of RDI with no significant effects on fruit quality and yield. González-Altozano and Castel (2000) concluded that implementing the RDI in Spain during July and August could save between 6 to 22% of irrigation water without affecting yield components or fruit quality. However, continuous RDI during September and October resulted in significant reductions in fruit size and external peel disorders (creasing) in a large proportion of the fruits of clementina de nules. Mostert and Van Zyl (2000) obtained similar findings on citrus fruit quality under water stress and indicated that the total soluble solids (TSS) and the acidity of juice decreased with increased volume of water applied. Also, single regulated deficit irrigation regimes reduced irrigation by 13–24%, while combined regime reduced it by 23–35%.

Understanding the impact of RDI on crop production requires assessment for several years. This was emphasized by Girona et al. (2005 a, b) who indicated that fruit production of almonds had been affected by deficit irrigation after four years of the irrigation regime when fruit set decreased slightly and significantly reduced vegetative growth of the trees. During the first two experimental years, dry matter accumulation did not decrease with drought in the RDI treatment. However, both vegetative and kernel growth were reduced during the third and fourth years of the experiment. A possible explanation for this decrease was attributed to a hypothetical depletion of the carbohydrate reservoir in trees under RDI and also to the negative soil water balance. Overall, the results indicated that regulated deficit irrigation could be used successfully on peach trees grown in deep soils. The response to deficit irrigation would be also affected by the soil wetting pattern and rooting depth (Girona et al. 2002).

Obviously, the effects of RDI on crop yield and the substantial water savings require further studies and research to evaluate the impacts and benefits of this irrigation practice. Therefore, in-depth research is needed to evaluate the concept of deficit irrigation (DI) as a mean of reducing irrigation water use while maintaining or increasing farmers’ profits. The objectives of study were to evaluate the effects of DI on yield and quality of lemon grown in the middle Jordan
Valley and to determine the actual evapotranspiration of citrus under different levels of water stress.

MATERIALS AND METHODS

Field experiment

The experiment was conducted at the Agricultural Research Station of the University of Jordan (ARS-UJ) in the central Jordan Valley for three consecutive years in the period 2005-2007. Jordan Valley is the main irrigated area in Jordan that extends between 31°46’ N to 32°40’ N latitudes and between 35°32’ E to 35°40’ E longitudes, with an elevation ranging from 200 m below mean sea level (bmsl) in the north to about -400 m (bmsl) near the Dead Sea in the south. The valley is characterized by semi-arid climate with annual precipitation ranging from 150 mm in the south to more than 400 mm in the north. The valley exhibits a very favorite climate to grow vegetable and many sub-tropical fruits and citrus in the winter. The experiment site, which is located in the Central Jordan Valley at 32°10’ N Latitude and 35°37’ E longitude and altitude of -230 m (bmsl), has been selected in the citrus orchard of the ARS-UJ where 108 lemon trees have been identified as a test plot. The area of the plot is 54 m × 72 m of about 3888 m². The Central Jordan Valley has a warm climate in winter with a minimum temperature of 8.5 °C in January and a hot summer with a maximum temperature of 40.4 °C in July. The yearly average maximum and minimum temperatures are 30.9 and 18.5 °C, respectively, while the yearly mean temperature is 24.7°C.

Soil of the study site is located within a soil mapping unit that has ustochreptic and ustolic camborthid with some ustic torriorthent and torrifluvent with hyperthermal temperature regime (MoA, 1995). Soil texture is mainly sandy loam with a bulk density of 1.62 g cm⁻³. The average soil salinity was about 0.72 dS/m while salinity of irrigation water during summer ranged between 0.8 to 1.2 dS/m. The study was conducted on full-grown citrus orchard (10-year old) using three treatments replicated three times in a completely randomized block design. Percent of soil area covered by the canopies of the trees was found to be 80%. The irrigation treatments were: T1 represents 100% irrigation calculated by multiplying FAO ET₀ by 0.64 as (a crop coefficient of 0.8 multiplied by ground cover of 0.8); T2 is 75% of full irrigation while T3 is only 50% of T1. Each treatment had 12 trees but measurements and readings were based on the two middle trees.

The yield, crop evapotranspiration, fruit quality and some phonological characteristics of the trees were evaluated. Four shoots were determined on the periphery of the selected trees using special tags, and length of these vegetative growths was measured every two weeks. Fruit quality was assessed through some external and internal quality measurements made on 25 randomly selected fruits from each treatment. The parameters included average fruit diameter and weight, total soluble solid (TSS) and titrable acidity (TA). Total yield for each treatment was estimated from the yield of the two middle trees of each replicate.

Estimation of Irrigation Water Requirements

The field was irrigated twice a week using a micro-irrigation system while the irrigation duration varied according to the irrigation depth applied for each treatment. Two drip irrigation lines with inline compensating emitters were used for each row in each replicate at a distance of 0.5 m from the tree trunk. The irrigation took place from the beginning of April to the end of November. However, the implementation of the different deficit treatments began in early June and continued until harvest late November. Leaching fraction of 20% was applied for the different treatments.
The daily crop evapotranspiration was obtained from the FAO-56 reference evapotranspiration (ET$_{o}$) approach and the actual evapotranspiration was estimated using the following water balance equation:

$$P + I - ET + R - D = \Delta W$$  \(1\)

where ET is actual evapotranspiration, P is the precipitation, I is the irrigation, R is the net surface runoff, D is the net drainage and $\Delta W$ is the change in storage of water which was estimated from the difference between the soil moisture readings. The deep percolation was assumed to be equal to the leaching fraction and net surface runoff was assumed 0.

CROP EVAPOTRANSPIRATION AND CROP COEFFICIENTS

Soil parameters that were used in the FAO-56 procedure to calculate crop evapotranspiration and crop and stress coefficients are presented in Table 1. A nearby weather station monitored air temperature, relative humidity, precipitation, wind speed, wind direction, solar radiation, barometric pressure and soil temperature at 5, 10 and 20 cm depths. The station and sensors were installed based on the guidelines of the World Meteorological Organization (WMO, 1981). All sensors were scanned at a one-second frequency and summarized every 15 minutes. At midnight, the daily extremes and totals were determined.

**Table 1: Soil parameters used in the FAO56-PM crop coefficient determination.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field capacity, $\theta_{FC}$</td>
<td>0.22 m$^3$ m$^{-3}$</td>
</tr>
<tr>
<td>Permanent wilting point, $\theta_{pwp}$</td>
<td>0.12 m$^3$ m$^{-3}$</td>
</tr>
<tr>
<td>Effective rooting depth, $Z_r$</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Total available water, TAW</td>
<td>150 mm</td>
</tr>
<tr>
<td>Readily available water, RAW</td>
<td>75 mm</td>
</tr>
<tr>
<td>The ratio of RAW to TAW, $P$</td>
<td>0.5 (fraction)</td>
</tr>
</tbody>
</table>

Daily grass reference ET (ET$_{o}$) was obtained using the FAO-56 approach. The FAO-56 Penman-Monteith equation for a grass reference crop is defined as (Allen et al., 1998):

$$ET_o = \frac{0.408(R_n - G) + \gamma \frac{900}{T + 273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$  \(2\)

where ET$_{o}$ is evapotranspiration (mm d$^{-1}$), $R_n$ is the net radiation (MJ m$^2$ d$^{-1}$), G the soil heat flux (MJ m$^2$ d$^{-1}$) and was assumed to be zero, T the mean daily air temp (°C), $u_2$ the mean daily wind speed at 2 m height (m s$^{-1}$), $e_s$-$e_a$ the saturation vapor pressure deficit (kPa), $\Delta$ the slope of the vapor pressure-temperature curve (kPa °C$^{-1}$), and $\gamma$ the psychometric constant (kPa °C$^{-1}$).

Root zone depletion ($D_r$), which may be defined as the water storage relative to field capacity, was calculated to assess the water stress conditions. Quantifying the soil water deficit (SWD) and its relation to canopy or leaf conductance is essential for application of the Penman–Monteith equation to water-stressed plants (Li et al., 2004). Root zone depletion is a good indication of soil water stress, because it helps in determining the water stress dates, severity, duration and reoccurrence. In addition, it can provide a practical means to monitor plant response to water stress, as the direct measurement of soil water content requires a priori unknowns of many soil and plant parameters that are difficult to measure (Nadler et al., 2003). Therefore, to evaluate the level of water stress under RDI with FAO 56-PM equation, a stress coefficient ($K_s$) was calculated as follows (Allen, 2000):

$$K_s = \frac{TAW - D_r}{TAW - RAW}$$  \(3\)

where $K_s$ is a dimensionless transpiration reduction factor and ranges from 0 to 1, $D_r$ is root zone depletion.
in mm, TAW is total available soil water in the root zone in mm, and RAW is readily available soil water in the root zone in mm. When $D_1 < RAW$, $K_s = 1$.

Crop evapotranspiration was obtained as:

$$ET_c = K_s K_c ET_o$$

where $ET_c$ is crop evapotranspiration (mm d$^{-1}$), $K_s$ is a water stress coefficient and $K_c$ is a crop coefficient. Water use efficiency (WUE) was calculated by dividing crop yield by the crop evapotranspiration under each irrigation treatment.

RESULTS AND DISCUSSION

Results showed differences in yield among the different treatments and among the three years of the experiment. Both of T1 and T2 had significantly higher yield than the T3 for the three years. For 2005, the total yield of T2 reached 28.6 ton/ha compared to 17.8 and 13.3 ton/ha for T1 and T3, respectively (Table 2). In 2005, the average fruit weight for T1 was significantly higher than that of T3 while T2 was intermediate. In the other two years, there were no significant differences in the average fruit weight among the treatments. Throughout the experiment, there were no significant differences in the average fruit diameter among the treatments. The TA was significantly higher for T3 than for the other two treatments in 2005 while no significant differences were evident in the other two years. Both TSS and TSS/TA were not significantly different in 2005 and 2006 while in 2007 it was higher for T1 than T3 whereas T2 was in between. These findings are in agreement with the results of Castel and Buj (1990), Domingo et al., (1996), Kanber et al., (1999) and González-Altozano and Castel (2000) who indicated that the impacts of DI on citrus varied with the level of DI and its duration. Water stress usually triggers flower formation and induced flowering in citrus and therefore results in increasing number of fruits per tree (Davenport 1990; Goldschmidt and Samach, 2004). Severe Water stress, however, resulted in reduced fruit weight and total yield.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (kg/tree)</th>
<th>Yield (Ton/ha)</th>
<th>Fruit wt (g)</th>
<th>Fruit diameter</th>
<th>TA (%)</th>
<th>TSS (%)</th>
<th>TSS/TA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>64.2ab</td>
<td>17.8ab</td>
<td>109.4a*</td>
<td>5.3</td>
<td>0.87b</td>
<td>9.5</td>
<td>10.9</td>
</tr>
<tr>
<td>T2</td>
<td>102.8a</td>
<td>28.6a</td>
<td>91.7ab</td>
<td>5.6</td>
<td>0.77b</td>
<td>9.8</td>
<td>12.7</td>
</tr>
<tr>
<td>T3</td>
<td>48.0b</td>
<td>13.3b</td>
<td>77.4b</td>
<td>5.3</td>
<td>1.05a</td>
<td>10.6</td>
<td>10.1</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>58.5ab*</td>
<td>16.3ab</td>
<td>141.0</td>
<td>6.0</td>
<td>0.64</td>
<td>7.8</td>
<td>12.2</td>
</tr>
<tr>
<td>T2</td>
<td>64.0a</td>
<td>17.8a</td>
<td>145.3</td>
<td>6.0</td>
<td>0.64</td>
<td>8.4</td>
<td>13.2</td>
</tr>
<tr>
<td>T3</td>
<td>46.3b</td>
<td>12.8b</td>
<td>134.0</td>
<td>5.9</td>
<td>0.71</td>
<td>9.0</td>
<td>12.7</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>72.0</td>
<td>20.0</td>
<td>122.1</td>
<td>6.30</td>
<td>0.77</td>
<td>9.6a</td>
<td>12.5a</td>
</tr>
<tr>
<td>T2</td>
<td>79.3</td>
<td>22.0</td>
<td>126.0</td>
<td>6.28</td>
<td>0.77</td>
<td>9.0ab</td>
<td>11.7ab</td>
</tr>
<tr>
<td>T3</td>
<td>62.5</td>
<td>17.4</td>
<td>118.6</td>
<td>6.22</td>
<td>0.77</td>
<td>8.6b</td>
<td>11.2b</td>
</tr>
</tbody>
</table>

* Means within column followed by different letters were significantly different at $P < 0.05$ using Fisher's LSD procedure (MINITAB Inc., 2004).
The annual grass reference evapotranspiration was 1429 mm in 2005, 1487 mm in 2006 and 1456 mm in 2007. Lemon evapotranspiration (ET$_C$) was 777, 690 and 562 mm in 2005; 798, 684 and 548 mm in 2006; 788, 688 and 555 mm in 2007 for T1, T2 and T3, respectively (Table 3). The total irrigation and precipitation amounts were 864, 747 and 629 mm in 2005; 813, 689, and 565 mm in 2006; and 830, 710 and 591 mm in 2007 for T1, T2 and T3, respectively. The application of DI resulted in saving of about 19% in the irrigation water amounts for T2 in the different years. For T3, irrigation water saving was 37% in 2005 and 2006 and 39% in 2007. This demonstrated that the DI of 75% full irrigation allows water savings up to 19% without affecting yield or its components, nor fruit quality. Subsequently, water use efficiency (WUE) was obviously improved under T2 treatment, particularly in the first year. The T1 treatment had the lowest WUE while T2 had the highest WUE and water productivity in the three years.

Table 3: Crop evapotranspiration, applied water (irrigation + rainfall), crop yield, water use efficiency (WUE), water productivity and water saving for the different treatments in 2005, 2006 and 2007.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ET$_C$ (mm)</th>
<th>Applied water (mm)</th>
<th>Yield (ton/ha)</th>
<th>WUE (kg/m$^3$)</th>
<th>WP ($/m^3$)</th>
<th>Water saving (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>770</td>
<td>864</td>
<td>17.8</td>
<td>2.3</td>
<td>1.2</td>
<td>0</td>
</tr>
<tr>
<td>T2</td>
<td>682</td>
<td>747</td>
<td>28.6</td>
<td>4.2</td>
<td>2.3</td>
<td>18</td>
</tr>
<tr>
<td>T3</td>
<td>555</td>
<td>629</td>
<td>13.3</td>
<td>2.4</td>
<td>1.3</td>
<td>37</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>793</td>
<td>813</td>
<td>16.3</td>
<td>2.0</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>T2</td>
<td>680</td>
<td>689</td>
<td>17.8</td>
<td>2.6</td>
<td>1.4</td>
<td>19</td>
</tr>
<tr>
<td>T3</td>
<td>545</td>
<td>565</td>
<td>12.8</td>
<td>2.4</td>
<td>1.3</td>
<td>37</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>788</td>
<td>830</td>
<td>20.0</td>
<td>2.5</td>
<td>1.3</td>
<td>0</td>
</tr>
<tr>
<td>T2</td>
<td>688</td>
<td>710</td>
<td>22.0</td>
<td>3.2</td>
<td>1.7</td>
<td>19</td>
</tr>
<tr>
<td>T3</td>
<td>555</td>
<td>591</td>
<td>17.4</td>
<td>3.1</td>
<td>1.6</td>
<td>39</td>
</tr>
</tbody>
</table>

The ten-day irrigation amounts, precipitation and actual evapotranspiration of lemon for the three years are presented in Fig. 1. The maximum ET$_C$ under full irrigation reached 4.6 mm/day in June of 2007. This finding indicates that the conventional crop water requirements that have been suggested by different consulting companies exceed the calculated ET$_C$ using these procedures. The irrigation and ET$_C$ were essentially the same for T1 throughout the irrigation period (from the beginning of April to the end of November) in 2005, 2006 and 2007. For T2 and T3 in the three years, ET$_C$ and the irrigation were quite close in April and May while ET$_C$ was higher than the irrigation from the beginning of June to mid of August. They were almost identical from mid of August until the end of October, where ET$_C$ was higher than the irrigation in November. During the deficit irrigation period, (From beginning of April to end of November) ET$_C$ was higher.
for T1 than for T2 and T3 and ET_c was higher for T2 than for T3 in the three years.

Water stress resulted in the deviation between the actual and potential ET_c due to shortage in the available water in the root zone. During the first three months of the year (before irrigation), the root zone depletion analysis showed that water stress did not take place in T1 in 2005 while in 2006 and 2007 it occurred in the first two weeks of January and during most of March (Fig. 2). The water stress for T2 happened in the first two weeks in January of 2005 while in 2006 and 2007 it happened in the first two weeks of January and during most of March. The water stress for T3 took place in the first two weeks of January in 2005 while in 2006 and 2007 it happened throughout the three months. During these three months, the existence of water stress and the length of this water stress depend on the amount and variation of rainfall and the soil moisture left from the irrigation from the previous year. During the full irrigation period (April and May), there was no water stress for T1 and T2 in the three years while for T3 water stress took place in April of 2005 and 2006 while it had no water stress in 2007. The water stress in April is due to the low soil moisture content at the beginning of April. During the deficit irrigation period, lemon trees in T3 were under water stress from early June to harvest. This resulted in lower shoot growth during summer, particularly in August (hottest month). For T2, the DI resulted in a water stress from mid of June to the end of October in the three years. The level of water stress and its periodicity under T2 treatment were less than those of T3.

Figure 1: Ten-day rainfall, irrigation and crop evapotranspiration for the different treatments in a. 2005, b. 2006 and c. 2007.
Results from this study showed that the 100% irrigation practice with FAO 56-PM equation resulted in no water stress for the different years. In December and after the cease of irrigation, no water stress took place for T1 in the different years. This could be attributed to the residual water stored in the soil after the full irrigation practice. For the same period, water stress was evident on several days in 2005 and on all the days in 2006 for T2 and T3. The severity of the water stress was significantly higher for T3 than T2 in the different years. The level of water stress ($K_s > 0.75$) under T2 during the different periods of 2005 did not affect the yield of that year. In 2006, the $K_s$ value reached 0.45 for T2 during March and early April. This level of water stress could explain the lower productivity of T2 in 2006 compared to 2005, as this growth period was considered as the first growth period for citrus (Davenport 1990; Domingo et al., 1996; Goldschmidt and Samach, 2004). In 2007, T3 and T2 had yield that was not significantly different from T1 even though water stress was evident for T2 and T3.

The trend of water stress during the 2005, 2006 and 2007 would indicate that water stress coefficient ($K_s$) showed good response to DI and performed well under water scheduling with FAO 56-PM equation. This confirms the findings of Li et al. (2004) who indicated that a climate-based soil water balance would provide better means of quantifying soil water deficit, under the application of Penman–Monteith equation, than a solely soil-based measurement. Therefore, this coefficient could be implemented in addition to soil water monitoring under DI practice.

**CONCLUSIONS**

The results revealed that the effects of the DI on the yield of citrus varied according to the level of deficit irrigation and the subsequent water stress. The use of 75% of crop evapotranspiration calculated from the FAO
56-PM resulted in significantly higher crop yield than the 50% level in 2005 and 2006 with some increase in yield and water use efficiency than the 100% irrigation practice. The use of 75% level of DI early June to late November would maintain the total yield and save up to 19% of irrigation water amounts under the same experimental conditions. In this treatment, neither physical nor chemical lemon characteristics were significantly modified. In consequence, this treatment appears to be a promising irrigation strategy in areas with scarce water resources and similar to our study area, providing that a water stress coefficient of more than 0.75 is maintained. When deficit irrigation is applied during a critical period, crop production decreases. Regulated deficit irrigation strategies by applying adequate irrigation amounts during the critical period and reducing irrigation during the non-critical phonological periods, are able to obtain adequate crop yield and save substantial amounts of water.

The importance of this research is to reflect the current practices of restricted irrigation supply imposed by the Jordan Valley Authority due to shortage of water availability and to regulate it in order to obtain profitable productivity. During the years of drought water supply in the summer is limited to citrus growers while water is not allowed for the cultivation of summer field crop and vegetables. The water shortage in the Jordan Valley in the summer exists most of the years with average annual rainfall. Surplus of water supplies may be available only on wet years which can happen once or twice every ten years. The results of the three years of research can generate a set of DI recommendation for farmers, water managers and irrigation extension agents to reduce water using by up 20%. This strategy can be integrated into the general national policy of irrigation water management at the farm levels and the project level. The results of this research could be scaled up to demonstration level, in many farms and further be disseminated to the whole citrus growers’ community in the Jordan Valley.

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REFERENCES

FAO (Food and Agriculture Organization) (2002). Deficit irrigation practices, water reports 22, FAO publications, Rome, Italy.


للماء ونتاجية الاحتياط على المياه الزراعية تحت الري تأثير الأردن وادي في الكرة وجدان سليمان ويمن شطنة رشيد محمد *

*ملخص* 

إنتاجية عليه الرية تأثير دون الماء كفاءة الإدارة كاستراتيجية المياه الزراعية تحت الري سياسة الإمكانيات يمكن في خصائص الأردن مثل المياه الموارد محدودة البلاد.

للدراسة الأردن وادى المنطقة في البحث هذه اجريت فقد الغرض، ولهذين الماء والنتاجية الاحتياط تحت الري متسوية تأثير.

المقدمة: 

(2005، 2006، 2007 (ت1) I لعمليات متسوية تحت النمو كاملاً للماء، تتمثل الأولى الأمانة في 100% من الري، ثانية الأمانة تتمثل؛ T2 (الثانية الأمانة وتتمثل؛ T3 (الثانية الأمانة في أساس على فيها الري تتم فقد 50% الأولية الأمانة تشمل)

تظهر للاجئان الثالثية الأمانة تحت الماءأشجار تعرض الثلاث، لسنوات الجذور للمنطقة الرطبية التحليل للمعاملات الأولى تشير إلى NA إلى أوائل أغسطس (T1) إلى أوائل يوليو (T2) إلى أوائل يونيو (T3) الهواء في الاختلافات في الهواء تحت الماء، هذه الأمانة لا تصل إلى 30% لفي نهائية نهاية أي تموز متبوعة خلال الفترة، نهاية وحتى تموز تبديد في الرطبية الهادئ.

الامانة والماء، ونتاجية و主营 نسبة وصول التواليا، على وثالث الأمانة للنينانية، التحقيق في عمليات مبتدأ في الرطبية للماء، ونتاجية، وهما، في الأردن وادي لالة، في الحمضيات الزراعية على المياه الزراعية تحت الري سياسة تعميم بعدها لتمكناً حقلية مشاهدات.

الكلمات الدالة: الأردن وادي، الماء، الزراع، الري، سياسة استماع، بعدها، حقلية.

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