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# Utilizing Deficit Irrigation to Enhance Growth Performance and Water-use Efficiency of Eggplant in Arid Environments

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## ABSTRACT

**The objective of this research was to investigate the effects of deficit irrigation on physiological and agronomic terms of eggplant to maximize the Water Use Efficiency (WUE) without affecting the final yield and fruit quality parameters under arid environment. Therefore, two field experiments were conducted at two different sites: Ghor Al-Safi, Jordan Valley and Sail Al-Karak, Karak Valley, Karak Province, Jordan, using a common eggplant cultivar (Classic) using five irrigation levels: 20, 40, 60, 80, and 100% based on field capacity. The most stressful Deficit Irrigation (DI) treatments (40 and 20%) resulted in significant effects on leaf area, leaf relative water content, leaf water potential and leaf mineral content. Biochemical parameters also showed an increase in proline and a decrease in chlorophyll content under water deficit conditions. Fruit weight and total yield decreased with DI. The control (100% irrigation treatment) plants revealed higher nutrient contents than the water-stressed plants. The fruit TSS and titratable acidity were increased at both sites as the irrigation regime decreased from 100 to 20%. Fruit nutrient content decreased with increasing water deficit. However, the differences were not significant between the control (100% irrigation treatment) and the 80% irrigation treatment. The 80% treatment showed high water use efficiency with relatively small effects on plant growth performance compared with the control. As a result, DI level at 80% can be utilized to increase *WUE* without a significant effect on crop growth performance.**

**Keywords:** Arid and semi-arid environments, Crop quality, Deficit irrigation, Water use efficiency, Yield.

## INTRODUCTION

Water shortages in Mediterranean countries, mainly in arid and semi-arid zones are one of the main limiting factors in irrigated agriculture. Jordan is considered to be one of the ten poorest countries worldwide in water resources (Shatanawi *et al.*, 2007). The agricultural irrigation amount allocated for irrigation decreased through the period 1985–2008 (78% in 1985 to 60% in 2008) (Shatanawi *et al.*, 2007). Although irrigated areas increase to satisfy high population growth, a great amount of water resources will be diverted from agriculture to balance the growing water demand from municipal and industrial sectors (Correia, 1999). Because of this, it is necessary to implement efficient irrigation management strategies.

The shortage of water resources may prevent additional growth of irrigated agriculture (Mohawesh and Al-Absi, 2009). In several countries, renewable water resources have already been exceeded. This has resulted in declining groundwater levels and water quality deterioration (Shatanawi *et al.*, 2007). The overuse of water resources possibly will reach a crisis degree (Gleick 2000; Mohawesh and Karajeh, 2014). Consequently, for sustainable irrigation water resources, it has become an imperative concern to enhance crop Water Use

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Efficiency (WUE) through suitable irrigation design and management. Deficit Irrigation (DI) has been commonly used as a suitable strategy in arid and semi-arid regions (Mohawesh *et al.,* 2010; Mohawesh and Karajeh, 2014) where water is the most limiting natural resource. DI has been applied productively on field crops. Kirnak *et al*. (2001) evaluated the effects of irrigation regimes (100, 80, 60, and 40% of Pot Capacity (PC)) on eggplant. They showed that plants grown under a lower irrigation regime had less fruit yield and quality, considerable decreases in chlorophyll content, lower leaf Relative Water Content (RWC), and less vegetative growth than those in the control treatment. Abd El-Aal *et al.* (2008) investigated the effects of irrigation interval (10 and 21 days intervals) on eggplant growth performance. They found that plant growth, total yield, and fruit physical and chemical properties were better when eggplant was irrigated at 10-day intervals. Since DI affects plant growth performance, yield, and fruit quality, it is an urgent issue to examine the degree of water deficit that can be applied without major losses in crop production under different conditions. Therefore, the aims of this work were to study the main effects of water stress on physiological and agronomic terms, and to define the threshold values of water stress to maximize the water use efficiency without affecting the final yield and fruit quality parameters.

## MATERIALS AND METHODS

### Description of the Experimental Sites

Two experiments were conducted at two sites: Ghor Al-Safi (31° 3' 38" N; 35° 29' 13" E, -384 m asl) from September 15, 2012 until February 15, 2013 and Sail Al-Karak (31° 12' 1" N; 35° 41' 37" E, 681 m asl) from February 15, 2013 until July 15, 2013, Karak Province of Jordan at private farms. The Ghor Al-Safi site has a subtropical climate with an annual average temperature and rainfall of about 25°C and 83 mm (1986–2010), respectively. The Sail Al-Karak site has long-term averages of temperature and rainfall of about 18°C and 250 mm (1986–2010), respectively.

### Description of the Experimental Design and Treatments

Two field experiments were conducted using a common eggplant cultivar (Classic). The sites were prepared for planting by plowing, disking, and leveling. A drip irrigation system was used. Polyethylene drip laterals (20 mm inside diameter) were installed before planting, with emitters (rated at 8 l $h^{-1}$ discharge) spaced every 0.3 m on the laterals. A buffer zone with spacing of 1.0 m was provided between each treatment. Experimental treatments were arranged using a Randomized Complete Block Design (RCBD). The eggplant crop was fertigated 5 times during the growing season according to the traditional agricultural practices in the area. A total of 450 kg urea $ha^{-1}$ (46% N), 250 kg $ha^{-1}$ ammonium sulfate, and 720 kg $ha^{-1}$ NPK (20:20:20 with trace elements) fertilizers was applied by fertigation. In the application of the fertilizer, a pressure differential was formed by throttling the water flow in the control head and diverting a fraction of the water through a tank containing the fertilizer solution. The fertigation period was dependent on the lowest DI level duration (Mahadeen *et al.,* 2011). 5-week-old (0.10 to 0.15 m height) eggplant transplants were planted on 15 September and 15 February at Ghor Al-Safi and Sail Al-Karak, respectively. Each experiment consisted of five treatments with three replications per treatment. The laterals were mulched with 80 cm wide black plastic. Row spacing was 160 cm, while the plant spacing was 30 cm.

A single row of plants was grown in the middle of the plastic mulch with a single lateral for each row, with 100 plants per row and 500 plants per plot, thus the total





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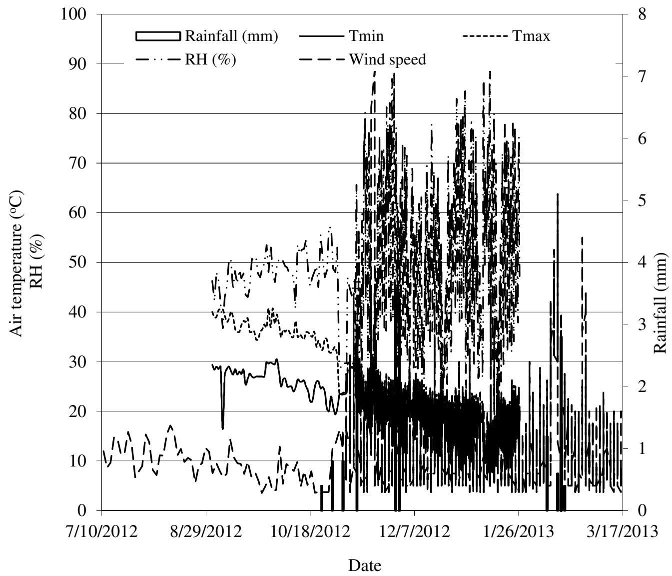
number of plants were 1,500 for the whole experiment.

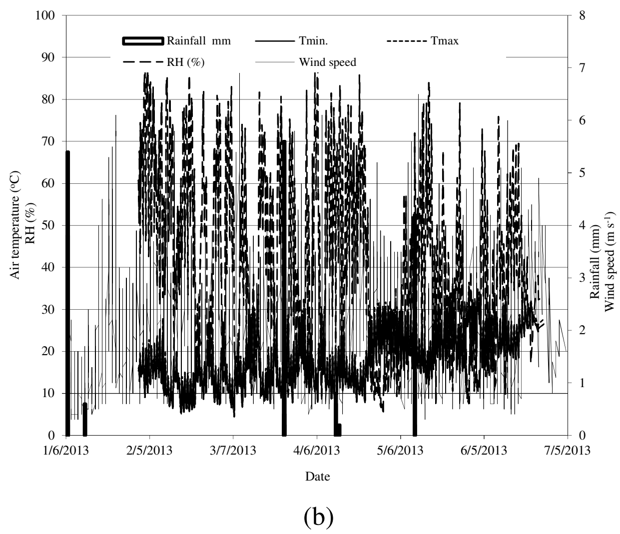
Experimental treatments consisted of five irrigation regimes (20, 40, 60, 80, and 100% based on Field Capacity (FC)) based on Crop Consumptive Use ($ET_c$). All treatments were irrigated initially with the same amount of water for two weeks to achieve uniform initial water content and to reach *FC*. Irrigation treatments were commenced two weeks after transplanting. The measured meteorological data from the installed weather station inside the field were used to calculate the reference Evapotranspiration ($ET_o$) [Figure 1 (a, b)]. The $ET_o$ was calculated using the locally calibrated Hargreaves model (Mohawesh and Talozi, 2012) [Equation (1)].

$$ET_o = 0.408x0.6957x0.0023(T_{mean} + 16.6)(T_{\max} - T_{\min})^{0.58} R_a \quad (1)$$

Where, $ET_o$ is the reference evapotranspiration in mm day$^{-1}$, $T_{max}$, $T_{min}$,




(a)




(b)

**Figure 1**. Meteorological data during the experiment at Ghor Al-Safi (a) and Sail Al-Karak (b) sites during the experiment period.

and $T_{mean}$ are the maximum, minimum, and mean air temperatures (°C), respectively, and $R_a$ is the extraterrestrial radiation (MJ $m^{-2}$ $day^{-1}$). The $ET_c$ was calculated by multiplying $ET_o$ by the Crop Coefficient ($K_c$): $ET_c = K_c \times ET_o$ as recommended by Allen *et al*. (1998). The local estimated $K_c$ values for plastic mulched drip irrigated open-field eggplant used in this study were 0.60, 0.85, 1.10, and 0.95 during the four growth stages (30 days per stage) (Jordan valley authority, 2006) [Equation (2)]. These $K_c$ values were used at both sites of experiments.

## Soil Properties Measurements

Soil samples from three depths (0–15, 15–30, 30–60 cm) from the eggplant fields were collected in triplicate. The soil samples were dried and crushed, then sieved using 2 mm sieve. Soil texture was determined by the hydrometer test (Klute, 1986). Table 1 shows the main soil chemical properties analyzed according to the standard procedures of the United States Salinity Laboratory Staff (USSL, 1954). The soil moisture content was measured using Moisture Sensor-ML2x (Delta-T Devices Ltd) and profile time domain reflectometry PR2 (Delta-T Devices Ltd). The soil water potential was measured weekly before and after each irrigation event using one tensiometer at the depth of 20–30 cm (Soil Moisture Equipment Corporation, Santa Barbara, Calif.) for each treatment. The soil moisture measurements were done using three probes for each treatment (one probe for each replicate) once per week. The PR2 was used to measure soil moisture at a 60 cm soil depth. Soil properties of the soil samples used in this study are presented in Table 1. The soil textures were sandy loam and clay loam in Ghor Al-Safi and Sail Al-Karak, respectively. The alkalinity (pH), soil Electrical Conductivity (EC), soil Nitrogen Content (N), and soil Phosphorous Content (P) at Ghor Al-Safi showed higher values than at the Sail Al-Karak site. The soil samples had *EC* values ranging from 2.46 to 6.34 and 1.51 to 2.22 dS $m^{-1}$ at the Ghor Al-Safi and Sail Al-Karak sites, respectively. The *EC*, N, P, K, and OM tended to decrease with soil depth at both sites (Table 1).

## Plant Properties Measurements

Two months after plant transplanting, leaf samples were collected at midday to analyze the chloroplast pigments, proline, Leaf Nitrogen Content (NL), Leaf Phosphorus Content (PL), and Leaf Potassium Content (KL) in triplicates. Leaf samples were stored in plastic bags with wet tissue paper at 4°C. The measurements were carried out on the leaves within two days of cutting to estimate total chlorophyll content (Inskeep and Bloom, 1985). Leaf proline content was

**Table 1.** Physical and chemical properties of soil at Ghor Al-Safi and Sail Al-Karak sites.

| Soil sample/Depth (cm) | pH [a] (-) | *EC* [b] (dS $m^{-1}$) | N [c] (%) | P [d] (ppm) | K [e] (ppm) | OM [f] (%) | Sand (%) | Silt (%) | Clay (%) | *FC* [g] (%) | *PWP* [h] (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ghor Al-Safi | | | | | | | | | | |
| 0-15 | 8.29 | 6.31 | 1.45 | 445.62 | 15.08 | 1.12 | 62 | 16 | 17 | 34 | 22 |
| 15-30 | 8.37 | 3.50 | 1.38 | 433.42 | 14.54 | 1.01 | 64 | 18 | 18 | 34 | 23 |
| 30-60 | 8.53 | 2.36 | 1.43 | 435.32 | 8.25 | 0.39 | 65 | 15 | 20 | 35 | 23 |
| | Sail Al-Karak | | | | | | | | | | |
| 0-15 | 7.10 | 2.26 | 0.24 | 364.23 | 18.14 | 1.24 | 42 | 20 | 38 | 38 | 23 |
| 15-30 | 7.11 | 1.45 | 0.20 | 362.35 | 18.42 | 0.98 | 45 | 25 | 30 | 35 | 22 |
| 30-60 | 7.10 | 1.43 | 0.20 | 297.36 | 11.46 | 0.83 | 40 | 30 | 30 | 34 | 23 |

[a] Alkalinity (-); [b] Electrical conductivity (dS $m^{-1}$); [c] Nitrogen content (%); [d] Phosphorus content (ppm); [e] Potassium content (ppm); [f] Organic matter (%); [g] Field capacity(%), [h] Permanent Wilting Point (%).





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measured using Bates *et al.* (1973) method based on leaf dry weight (mg $g^{-1}$). Subsequently, each leaf sample was dried at 75°C for three days then ground. The ground leaf samples were used to determine the total NL, PL, and KL in the plant leaves. The PL was analyzed by a vanadate-molybdate method (Kirnak *et al.,* 2001) using a UV/visible spectrophotometer (Bausch and Lomb, Belgium). The KL was analyzed using a Flame photometer (Corning 400, UK) (Kirnak *et al.,* 2001). The NL was determined using the Kjeldahl method (Chapman and Pratt, 1982). Additional leaves were examined for Relative Water Content (RWC), Leaf Water Potential ($\psi_w$), and Leaf Area (LA) measurements for each treatment in triplicate at the same time (two months from plant transplanting). The *RWC* was calculated according to Barrs and Weatherley (1968) method. The leaf was weighed directly [Fresh Weight (FW)] after collection. Then, it was placed in a petri dish containing wet filter paper and stored at 4°C. After 24 hours, the leaf Turgid Weight (TW) was measured. Then, the leaves were oven-dried for 24 hours at 75°C and weighed [Dry Weight (DW)]. Midday Leaf Water Potential ($\psi_w$) was measured using a pressure chamber (PMS Instruments Co., Corvallis). The leaves were mature, similar in age, fully expanded, and exposed to solar radiation. The *LA* was measured using the photoelectric method (Cox, 1972).

### Yield Quantity and Quality Analysis

The yield was harvested six times during the growing season. The growth season was four months at both sites. The yield and fruit weight were recorded for each treatment. Ten fruits were used to calculate the average fruit weight for each treatment. The total yield for each treatment was calculated by summing the total harvested yield during the experiment. Three fruits were used to measure Total Soluble Solids (TSS) in triplicates. Fruits were pressed to get juice, which was used to find out TSS with a digital refractometer (Atago Co., Ltd, Tokyo, Japan). A 5 g sample of the same juice was diluted with 50 ml of deionized water. The diluted samples were titrated with 0.1N NaOH to determine titratable acidity. Five random fruit samples were selected from each harvest time and replicate. The five fruit samples were combined for each replicate. In total, there were fifteen fruit samples for each treatment. Each combined sample was dried at 75°C for one week. Finally, fruit samples were ground. The powdered samples were used to determine Fruit Nitrogen Content (NF), Fruit Phosphorus Content (PF), and Fruit Potassium Content (KF). The analysis procedures were the same as the leaf analysis methods. Plant Water Use Efficiency (WUE) was calculated as the total harvested yield divided by the amount of irrigation water applied during the growth period (Mohawesh and Karajeh, 2014).

### Statistical analysis

Data were analyzed using a General Linear Model (GLM) procedure (SPSS software version 11.5; SPSS Inc., Chicago, USA). A Least Significance Difference (LSD) test was used for mean separation at a level of significance of 0.05. Mean values of leaf chlorophyll content, proline, NL, PL, KL, *RWC,* $\psi_w$, *LA*, yield weight, fruit weight, TSS, titratable acidity, NF, PF, KF, and *WUE* were compared between five irrigation levels (100, 80, 60, 40, and 20% based on FC).

## RESULTS AND DISCUSSION

### Description of Soil Properties

The soil water content and soil water potential variations during the growth period are shown, for example, in Figure 2 for Sail Al-Karak site. The mean soil water contents were about 23.0, 26.0, 29.0, 31.0, and 33.0% at 10–15 cm soil depth measured using





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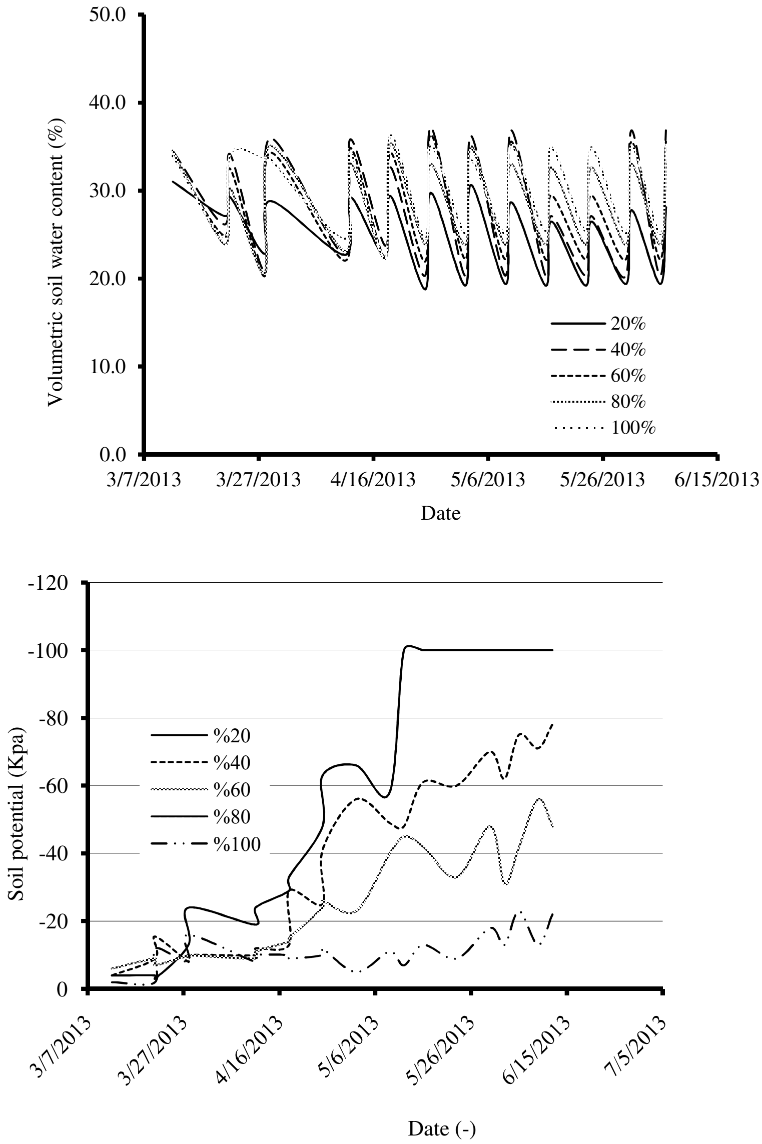


**Figure 2.** Soil moisture content and soil water potential during the experiment at Sail Al-Karak sites.

Moisture Sensor-ML2x (Delta-T Devices Ltd) for 20 40, 60, 80, and 100% irrigation levels at Sail Al-Karak site, respectively. The soil water potential decreased with decreasing irrigation water (Figure 2). The soil water potential values were less than −100, −60 to less than −80, −35 to −50, −20 to −35 and −10 to −20 kPa at 20–30 cm depth for 20, 40, 60, 80, and 100% irrigation levels at Sail Al-Karak site, respectively (Figure 2).

## Plant Properties Measurements and Analysis

Table 2 shows the effect of irrigation levels on *LA, RWC,* $\psi_w$, proline, chlorophyll, NL, PL, and KL content. The differences were not significant between the 100% irrigation level and the lower level of water stress (80 and 60%) except for *LA* at Ghor

**Table 2.** Effect of deficit irrigation regimes on eggplant leaf area, relative water content, plant water potential, proline, chlorophyll, nitrogen, phosphorus and potassium content at Ghor Al-Safi and Sail Al-Karak sites.

| Irrigation regime (%) | *LA* [a] ($cm^2$) | *RWC* [b] (%) | $\psi_w$ [c] (MPa) | Proline (ppm) | Chlorophyll (ppm) | NL [d] (%) | PL [e] (ppm) | KL [f] (ppm) |
|---|---|---|---|---|---|---|---|---|
| | | | | Ghor Al-Safi | | | | |
| 100 | 60.22a | 78.33a | 0.250b | 10.23b | 2386.85a | 4.83a | 341a | 7730a |
| 80 | 44.49b | 76.67a | 0.250b | 9.38b | 2486.21a | 4.59a | 342a | 7553a |
| 60 | 33.40c | 72.77ab | 0.333ab | 10.89ab | 2312.67a | 4.67a | 349a | 6553ab |
| 40 | 31.19c | 72.43b | 0.433a | 16.16a | 2196.57b | 4.63a | 322b | 6506b |
| 20 | 26.19c | 72.64b | 1.133a | 13.96a | 1945.47b | 3.70b | 325b | 6096b |
| | | | | Sail Al-Karak | | | | |
| 100 | 193.36a | 86.30a | 0.83c | 6.90b | 1416.57a | 4.41a | 1062a | 4143a |
| 80 | 184.15a | 83.01a | 1.07bc | 9.39b | 1329.74ab | 4.56a | 365b | 4080a |
| 60 | 130.57ab | 81.91ab | 1.13b | 10.89ab | 1198.00bc | 4.42ab | 365b | 4313a |
| 40 | 109.48b | 81.67b | 1.47a | 16.16ab | 1064.51cd | 4.21ab | 185c | 4253a |
| 20 | 106.77b | 80.68b | 1.57a | 20.63a | 923.70d | 3.91b | 263c | 4040b |

[a] Leaf Area ($cm^2$); [b] Relative Water Content (%); [c] Plant Water Potential (bar); [d] Leaf Nitrogen Content (%); [e] Leaf Phosphorus Content (ppm), [f] Leaf Potassium Content (ppm). Means within columns followed by the same letters are not significantly different at 0.05 probability level using L*SD* test.

Al-Safi. However, high levels of water stress (40 and 20%) showed a significant effect on *LA, RWC,* $\psi_w$, proline, chlorophyll, NL, PL, and KL content comparing to control treatment (100%) (Table 2). The water deficit reduced the growth of eggplant components. The *LA* was reduced from 60.22 and 193.36 $cm^2$ for 100% irrigation level to 26.19 and 106.77 $cm^2$ for 20% irrigation level at Ghor Al-Safi and Sail Al-Karak, respectively. The results of *LA* obtained at the two sites were different because plant growth depends on the season, climatological conditions, and many other factors including soil fertility and salinity. This is in agreement with Mohawesh and Karajeh (2014) who showed a decrease of *LA* under water deficit. The highest *RWC* values were for a lower level of water stress (100 and 80%). The decrease in plant *RWC* under drought stress may possibly depend on plant vigor reduction (Liu *et al.,* 2002). The *RWC* decreased from 78.33 and 86.30 for 100% irrigation level to 72.64 and 80.68% for the 20% irrigation level at Ghor Al-Safi and Sail Al-Karak, respectively. These results are in agreement with Mohawesh and Karajeh (2014) who found that leaf *RWC* decreased with deficit irrigation treatments under greenhouse conditions. Plants at different irrigation levels showed obvious variations in $\psi_w$. The $\psi_w$ decreased with decreasing irrigation quantity. The 100% and 80% irrigation regimes showed higher $\psi_w$ than those of the stressed irrigation levels. The $\psi_w$ was −0.25, −0.25, −0.333, −0.433 and −1.133 MPa at Ghor Al-Safi site and -0.83, -1.07, -1.13, -1.47 and -1.57 MPa at Sail Al-Karak site for 100, 80, 60, 40, and 20% irrigation levels, respectively. Our results are in agreement with Javadi *et al.* (2008) who also found a similar decrease of $\psi_w$ as a result of water deficit. Similar observations were also reported for eggplant during and after repetitive water stress (Sarker *et al.,* 2005).

Biochemical parameters showed an increase in proline and a decrease in chlorophyll content under water deficit. Proline concentration in leaves increased significantly with increasing water deficit. The proline concentration increased by 36.46 and 198.98% for the 20% irrigation level at Ghor Al-Safi and Sail Al-Karak, respectively (Table 2). Water deficit induced an increase in proline synthesis with





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**Table 3.** Effect of deficit irrigation regimes on eggplant yield, fruit weight, total soluble solids, nitrogen, phosphorus and potassium content at Ghor Al-Safi and Sail Al-Karak sites.

| Irrigation regime (%) | Yield (Kg ha$^{-1}$) | Fruit Wt. (Kg) | TSS [a] (%) | Acidity (%) | NF [b] (%) | PF [c] (ppm) | KF [d] (ppm) | *WUE* [e] (Kg m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| | | | | Ghor Al-Safi | | | | |
| 100 | 27840a | 0.63a | 5.33b | 0.1117c | 3.38a | 389a | 7017a | 5.13c |
| 80 | 26020a | 0.50ab | 6.33b | 0.1340a | 3.20a | 357a | 6935a | 6.00c |
| 60 | 16687b | 0.36b | 7.00a | 0.1787a | 3.10a | 377a | 7017a | 7.58b |
| 40 | 11138c | 0.22c | 7.00a | 0.1117c | 3.01ab | 358a | 5704ab | 7.13b |
| 20 | 10057c | 0.20c | 6.67a | 0.1227b | 2.24b | 317b | 4718b | 8.49a |
| | | | | Sail Al-Karak | | | | |
| 100 | 28290a | 0.32a | 3.00c | 0.12b | 3.56a | 1930ab | 5760a | 2.78c |
| 80 | 21000a | 0.29ab | 3.65bc | 0.14b | 3.25a | 1755a | 5300b | 3.56c |
| 60 | 15600b | 0.22b | 4.00b | 0.16b | 3.17ab | 1611ab | 4445c | 3.85c |
| 40 | 12540b | 0.14c | 4.33b | 0.23a | 3.12b | 1493c | 3870c | 3.07b |
| 20 | 9630c | 0.10c | 5.00a | 0.24a | 2.58c | 1438c | 3865c | 4.73a |

[a] Total Soluble Solids (%); [b] Fruit Nitrogen Content (%); [c] Fruit Phosphorus Content (ppm), [d] Fruit Potassium Content (ppm). Means within columns followed by the same letters are not significantly different at 0.05 probability level using *LSD* test.

decreasing irrigation level. An increase in leaf proline content with an increase in water deficit levels was also reported in several studies (Yoshiba *et al.,* 1997; Heuer and Nadler, 1998). Chlorophyll content decreased as proline content increased. Water deficit significantly reduced leaf nutrient (NL, PL, and KL) content (Table 2). The control plants showed higher nutrient contents than the water-stressed plants. The highest significant content was found at 100% and the lowest was at the 20% irrigation level. For example, the NL concentration was 4.83 and 4.4% for the 100% irrigation level while it was 3.70 and 3.91% for the 20% irrigation level at the Ghor Al-Safi and Sail Al-Karak sites, respectively. Bharambe and Joshi (1993) and Honda (1971) found that the plant uptake of N, P, and K was adversely affected under water deficit.

## Yield Quantity and Quality Analysis

Table 3 shows the effect of DI regimes on yield, fruit weight, TSS, titratable acidity, nutrient content (NF, PF, and KF), and *WUE*. A significant reduction occurred between 100, and 80%, and 60, 40, and 20% treatments at both sites. Eggplant yield weight for the 100% irrigation level was 27,840 and 28,290 kg ha$^{-1}$ and for the 20% irrigation level was 10,057 and 9,630 kg ha$^{-1}$ at the Ghor AL-Safi and Sail Al-Karak sites, respectively. These results are in agreement with Ebrahim *et al.* (2012), Aziz *et al.* (2013) and Demirel *et al.* (2014) who reported a similar decrease in eggplant yield under water deficit. Fruit weight also decreased significantly with water deficit.

The eggplant yield decreased with decreasing irrigation level (Figure 3). While the highest yield was obtained from the control treatment, the 80% treatment was in the same class in terms of yield values. The lowest yield was obtained from 20% irrigation level to which the lowest irrigation was applied. The relationship between the yield loss and irrigation water savings is shown in Figure 3. It shows a linear relationship between irrigation water savings and yield loss for the eggplant. Higher water savings result in high yield losses compared with control. Figure 3 also shows a similar response of eggplant yield to water stress at both sites.





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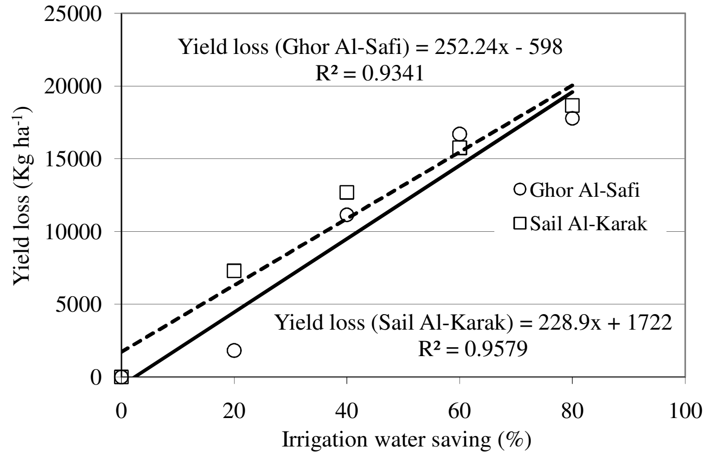


**Figure 3.** Yield loss with irrigation water amount saving at Ghor Al-Safi and Sail Al-Karak sites.

For fruit weight trait, the highest irrigation level treatment (100%) gave heavier fruits (630 and 320 g) in comparison with fruit weight values (200 and 100 g) of higher water stress (20%) treatment at Ghor Al-Safi and Sail Al-Karak sites, respectively (Table 3). These results were in harmony with Abd El-Aal *et al.* (2008) who found that fruit weight was significantly affected by DI regimes.

On the contrary, fruit quality traits (TSS and titratable acidity) increased as irrigation water decreased from the 100 to 20% level at both sites. There was no significant difference between the control (100%) and low water deficits (80%), however, significant differences were found between the control and the high water deficits (60, 40, and 20%). The TSS and titratable acidity increased significantly as the amount of irrigation water decreased from the 100% irrigation level to the 20% irrigation level at Ghor Al-Safi and Sail Al-Karak (Table 3). This is in agreement with Kirnak *et al.* (2002) who investigated the effects of DI on fruit yield and the quality of eggplant. They reported that TSS and titratable acidity increased with decreasing irrigation amounts from the 100 to the 20% irrigation level.

The fruit nutrient content of NF, PF, and KF decreased with water deficit. The highest significant differences were found between the 100% irrigation regime and the two lowest irrigation regimes (20 and 40%). The KF was 7,017 and 5,760 ppm for 100%, while it was 4,718 and 3,865 ppm for 20% irrigation treatments at the Ghor Al-Safi and Sail Al-Karak sites, respectively. These results are consistent with the findings of Simonne *et al.* (1998) and Kirnak *et al.* (2002) who reported for several vegetable crops that water deficit has a main function in decreasing fruit nutrient content. The least *WUE* was 5.13 and 2.78 kg $m^{-3}$ at 100% irrigation level while the highest value was for irrigation at 20% with 18.49 and 4.73 Kg $m^{-3}$ at Ghor Al-Safi and Sail Al-Karak, respectively. Amiri *et al.* (2012) showed the same trend as the highest *WUE* was obtained with the lowest irrigation treatment which was under no irrigation treatment.

## CONCLUSIONS

DI can be used to improve crop productivity per water unit to a certain extent. DI regimes affected plant physiological and agronomic parameters of eggplant. A significant reduction in plant growth performance occurred at 40 and 20% treatments at both sites as compared to the control. The *WUE* also decreased with increasing irrigation





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amount. The effect of low DI regimes (80%) was not significant compared to control, while high DI levels (60, 40, and 20%) significantly affected plant growth performance as compared to the control. A linear relationship between irrigation water savings and the yield loss for the eggplant was found. Higher water savings result in high yield losses compared with control. A similar response of eggplant yield to water stress was found at both sites. Based on our results, a DI level at 80% can be utilized to increase *WUE* without a significant effect on crop growth performance.

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# استفاده از کم آبیاری به منظور افزایش عملکرد رشد و کارایی مصرف آب گیاه بادمجان در محیط های خشک

ا. موحوش

## چکیده

هدف از این پژوهش، بررسی اثرات کم آبیاری بر ویژگی های فیزیولوژیکی و زراعی بادمجان به منظور به حداکثر رساندن راندمان مصرف آب (WUE) بدون تاثیر منفی بر پارامترهای عملکرد و کیفیت میوه نهایی در محیط مناطق خشک بود. بنابراین، دو آزمایش میدانی در دو محل مختلف: Ghor Al-Safi در دره اردن ، اردن و Sail Al-Karak در دره کراک، استان کراک، اردن با استفاده از یک رقم بادمجان مشترک (کلاسیک) در پنج سطح آبیاری: ۲۰، ۴۰، ۶۰، ۸۰ و ۱۰۰٪ ظرفیت زراعی انجام شد. شدیدترین تیمارهای کم آبیاری (DI) (۴۰٪ و ۲۰٪) منجر به اثرات قابل توجهی در سطح برگ، محتوای نسبی آب برگ، پتانسیل آب برگ و محتوای مواد معدنی برگ شدند. همچنین پارامترهای بیوشیمیایی افزایش پرولین و کاهش در میزان کلروفیل در شرایط کمبود آب را نشان دادند. وزن میوه و عملکرد کل با DI کاهش یافت. گیاهان تیمار شاهد (آبیاری ۱۰۰٪) محتویات مواد مغذی بالاتری نسبت به گیاهان قرار گرفته در معرض تنش آب را نشان داد. TSS و اسیدیته قابل تیتراسیون میوه در هر دو سایت با تغییر رژیم آبیاری از ۱۰۰٪ به ۲۰٪ افزایش یافت. محتوای مواد مغذی میوه با افزایش کمبود آب کاهش یافت. با این حال، تفاوت ها بین شاهد (تیمار آبیاری ۱۰۰٪) و تیمار آبیاری ۸۰٪ معنی دار نبود. تیمار ۸۰٪ راندمان مصرف آب بالا با اثرات نسبتا اندکی بر عملکرد رشد گیاه در مقایسه با شاهد نشان داد. در نتیجه، سطح DI ۸۰٪ می تواند برای افزایش کارایی مصرف آب بدون اثر قابل توجهی بر عملکرد رشد محصول مورد استفاده قرار گیرد.



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