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THE EFFECT OF IRRIGATION SCHEDULING ON CITRUS YIELD UNDER DRIP IRRIGATION IN THE JORDAN VALLEY

عميد كلية الدراسات العليا

BY

MOHAMED AL-AZHARI M. SALEH

Supervisor

DR. MUHAMMAD R. SHATANAWI

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COMMITTEE MEMBERS	SIGNATURE
1. DR. MUHAMMAD SHATANAWI **Associate Professor of Hydraulics and Irrigation Engineering** **(Advisor)**	M R Shatanawi
2. DR. IBRAHIM GHAWI **Associate Professor of Soil Physics** **(Member of Committee).**	I. O. Ghawi
3. DR. AHMAD ABU AWWAD **Associate Professor of Irrigation Engineering** **(Member of Committee)**	A. Abu-Awad
4. DR. ROSS HAGAN **Ph. D in Irrigation Engineering** **(Member of committe)**	Ross E Hagan

DEDICATION

MY WIFE
AND
MY SON AHMAD

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ABSTRACT

The effect of irrigation scheduling on citrus yield under drip irrigation in the Jordan Valley

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MOHAMED AL-AZHARI M. SALEH

Supervisor

DR. MUHAMMAD R. SHATANAWI

An experiment was conducted at an irrigated citrus farm located in the central Jordan Valley during the 1995 growing season to examine the possibility of saving water using estimated evapotranspiration for irrigation scheduling.

Four drip irrigation treatments were used on three citrus crops, these crops are: Clementine (*citrus reticulata* Blanco), King (*citrus nobitis* Lour), and Shamouti (*citrus sinensis* (L.) Osbeck).

The four irrigation treatments used were as:

(1) The amount of water was applied according to the evapotranspiration computed from climatic data using the Penman-Monteith equation (T_1

(2) The amount of water was applied according to the evapotranspiration computed using class-A pan evaporation (T_2).

(3) The amount of water was applied according to the evapotranspiration computed from climatic data using the Hargreaves equation (T_3).

(4) Water was applied for two and half hours duration each application (T_4).

There was no significant difference in fruit yield between the four irrigation treatments within the three varieties. However, the yield of T4 was slightly higher in clementine and king but the Pan evaporation method gave the highest yield in Shamouti.

Water use efficiency (WUE) values obtained from T4 were significantly lower than the WUE values obtained from the other irrigation treatments in clamentine and king, but in shamouti there was no significant difference in WUE between the four irrigation treatments.

The total amount of water applied during the season was significantly higher in T4 than the amount of water applied according to the other irrigation treatments.

Penman-Monteith, Pan evaporation, and Hargreaves appear to be satisfactory for the use by irrigators in the Jordan valley for scheduling irrigation and save considerable amounts of water.

1- INTRODUCTION

Water is a limiting factor in agriculture, especially in areas of limited water resources like Jordan. It is expected that by the year 2000, water demand in Jordan will rise to 1554 million cubic meters (MCM), of which about 1088 MCM will be utilized for agricultural purposes (1). However, the need for data on evapotranspiration and its use in determining when to irrigate and how much water to apply is very important for the purpose of water management.

The use of drip irrigation as a method of partial wetting of the root zone has become a common practice in the irrigation of vegetable crops and orchards in Jordan. Drip irrigation is one of the fast-growing technologies in agriculture and can result in water savings due to reduction of evaporation from non-wetted areas.

In the Jordan Valley, which is the major irrigated agricultural region in Jordan, one of the major crops irrigated by dripping is citrus. The total area planted with citrus in the Jordan Valley is 54000 dunum (2).

Farmers in the Jordan Valley cannot always apply water when it is needed. Sometimes they apply more water than the crop needs, which increase the losses both by deep percolation and evaporation from the soil surface.

This study was carried out to examine the possibility of saving water by scheduling irrigation on scientific basis using Penman-Monteith, Pan evaporation, and Hargreaves.

2. LITERATURE REVIEW

2.1 Irrigation Scheduling

Irrigation scheduling is defined as determining when to irrigate and how much water to apply, or as deciding when to start and when to stop an irrigation (3).

Criteria for scheduling irrigation varies from one situation to another. Where water is expensive, irrigation should be scheduled to maximize crop production per unit of applied water. Where good land is more expensive than water, irrigation should be scheduled to maximize crop production per unit of planted area. However, in certain situations, irrigation scheduling may be modified to minimize irrigation cost to facilitate farm operations (4).

The following approaches have been suggested by many researchers for scheduling irrigation:

1- Calculating a soil water budget using soils, crop, weather, and irrigation management information. This can be done simply by using hand calculation (Checkbook method) or by using computer models.

2- Monitoring soil water content with instruments or sampling techniques such as feel, gravimetric, gypsum blocks, tensiometers, and the neutron probe.

3- Observing and measuring plant indicators, such as when the crop show visible evidence of stress by color change, or leaf wilt, or by using canopy temperature measurements (5).

2.1.1 Use Evapotranspiration for Scheduling Irrigation

Consumptive use, or evapotranspiration is defined as the sum of two terms; (a) transpiration, in which water is entering plant roots and used to build plant tissue or being passed through leaves of the plant into the atmosphere, and (b) evaporation, in which water is evaporating from adjacent soil and water surfaces, or surfaces of leaves (6).

Evapotranspiration (ET) can be used to determine how much water has evaporated from a cropped field. Daily ET by a crop equals the depletion of water from the soil that day. Therefore, a record of accumulated ET between waterings can be used to determine when and how much irrigation water to apply (7).

Evapotranspiration is an important index for estimating irrigation water requirements; and subsequently for water resources management under condition where water is a limited resource (8).

CROPWAT is a computer program using the Penman-Monteith equation to calculate crop water requirements from climatic data. The program allows the development of irrigation schedules under different management conditions (9).

CRPSM is a model that can be used successfully to study irrigation scheduling possibilities, and so would be useful in reducing costs by suggesting those most promising for field experiments (10).

The pan evaporation, which has been developed at Utah State University, provides a satisfactory procedure for estimating evapotranspiration when climatic data are not available(11).

ET of mature orange trees was estimated under drip irrigation in Arizona. It was found that all equations predicted an evapotranspiration rate higher than the measured values during the winter, and except for the modified Penman equation, lower in summer (12).

Evapotranspiration (ET) of a developing citrus grove was determined by water balance from measured rainfall, irrigation, subsurface drainage, surface runoff, and the change in soil moisture storage. Annual ET ranged from 820 to 1280 mm and averaged 1090 mm across all treatments (13).

ET estimated by several methods was compared with measured ET for alfalfa. It was found that the equation developed by Hargreaves and Samani can be satisfactorily used to estimate potential evapotranspiration of an alfalfa reference crop (14).

ET was estimated in Saudi Arabia by the Blaney-Criddle, Jensen-Haise, Ture and Hargreaves equations. It was found that summer ET was underestimated by all equations. Winter ET was underestimated by Blaney-Criddle only, while a fair estimate of winter ET is given by the Hargreaves and Jensen-Haise methods (15).

ET was estimated under arid condition using several methods. The results showed the Jensen-Haise method gave the best estimate of ETp; followed by class-A pan evaporation, Hargreaves, modified Penman and Blaney-Criddle (16).

Evapotranspiration (ETc) of 2 years-old Kinnow mandarin trees was estimated from a field experiment, using a water balance equation. The yearly crop ETc was 124.46 cm and the daily rate of ETc, averaged for each month, ranged from 0.68 mm in Jan to 7.16 mm in June. For the purpose of scheduling irrigation, crop water use coefficient values of 0.71 to 0.87 for spring (Feb and Mar), 0.8 to 0.85 for summer (May and Jun), 0.64 to 0.95 for autumn (Sep and Oct), and 0.47 to 0.66 for winter (Dec and Jan) are suggested (17).

Estimates of potential crop evapotranspiration using the Penman equation and meteorological data collected within a mature citrus grove in Florida, from April 1988 to March 1989, were compared with class-A pan evaporation. It was found that daily ETp calculated from pan .evaporation was about 1 mm/day higher than that calculated with the Penman equation. It was concluded that either method of estimating ETp would be suitable for use in scheduling irrigation (18).

2.1.2 The effect of irrigation scheduling on citrus growth and yield

Irrigation scheduling is the most important factor affecting crop yield. Both time and amount of water applied has a great effect on yield and quality because at some crop growth stages excessive soil water stress, caused by delayed or inadequate irrigation, can irreversibly reduce the potential yield and quality of the crop or both (19).

Transpiration from Shamouti orange trees in partially irrigated plots (40% of the soil volume was irrigated) was 72% of the transpiration from the fully irrigated plots (100% of the soil volume was irrigated). The total production of flowers per tree was 120,000 in the partially irrigated plots as compared with 79,000 per tree in the fully irrigated plots. The flower abscission rate in the partially irrigated trees was higher than in the fully irrigated trees (20).

The average yield (for three years 1977, 1978, 1979) in a grapefruit grove drip-irrigated at 80% on 3- day intervals was 89 t/ha, compared with 98 t/ha in the 100% drip- irrigated plots. Water use efficiency was greater in the 80% irrigated plots, as compared with plots receiving full irrigation (21).

An experiment was conducted to study the growth response of young (Hamlin) orange trees to microsprinkler under field condition. Trees were irrigated when available soil water depletion (SWD) reached 20% (high frequency), 45% (moderate frequency) and 65% (low frequency). It was found that canopy volume, trunk cross-sectional area, .dry weight, shoot length, leaf area, total root dry weight, and new root dry weight were similar for the high and moderate irrigation frequency, but were significantly reduced at the low frequency (22).

Four drip irrigation treatments on sweet lime (*Citrus limetta*) were compared, 100%, 90%, 75%, and 60% of Class-A pan evaporation in 1987 and 90%, 60%, and 40% in 1988. Water was applied every other day through 4 l/h emitters, with 12-14 emitters per tree. The maximum fruit yield was produced at a pan evaporation fraction of 0.75 with maximum water use efficiency of 26.8 Kg/mm (23).

An irrigation experiment was conducted on a 10-years-old commercial Marsh Seedless grapefruit orchard during 1985-1988. Irrigation applications were made at intervals of 15 (I1) or 25 days (I2). The amount of irrigation water applied was based on a pan coefficient of 0.6 (K1), and 1.0 (K2). During the trial period, I1K2 and I2K2 treatments used more water. Average seasonal evapotranspiration for treatments I1K2 and I2K2 were calculated to be 1039 mm and 988 mm, respectively. There were no significant differences in grapefruit yield between irrigation treatment. The highest water use efficiency was obtained from treatment I1K1 in normal-years (24).

Five irrigation treatments on Valencia orange trees were compared. The five irrigation treatments were as follows (a) 900, (b) 450, (c) 675 liters of water were applied per tree when 600 liters of water had been used by lysimeter, (d) 990 liters were applied per tree when pan evaporation indicated a 55 mm requirement, or (e) 690 liters were applied when tensiometer readings fell to - 550 Kpa. Crop yields in treatments (a) to (e) were 166, 143, 195, 179, and 209 Kg/tree, respectively, and water application rates were 34.6, 17.7, 26.4, 30.7, and 23.0 m^3. Treatment (e) gave the highest net income. Use of a tensiometer rather than evaporation pan scheduling could save 2000 m^3 of water per hectare annually (25).

Irrigation scheduling of Valencia orange trees by means of lysimeter water usage, crop factor, and tensiometer were compared in a field trial. The highest net income was obtained with tensiometer scheduling using a total of 26.3 m^3 of water per tree annually (or 6750 m^3 per hectare), which produced 53.7 tons of fruit per hectare. The lysimeter trees used 12% less water, because of the difference in wetted area, which was almost 50% larger in the field trial (26).

In trials carried out during 1985-1988, mature orange cv. Salustiana trees grafted on sour orange rootstock were irrigated with (a) 60% of the estimated evapotranspiration from Class-A pan evaporation (control treatment), (b) at 80% of the control throughout the year, (c) at 60% of the control throughout the year, (d) at 60% of the control during the flowering and fruit setting period, or (e) at 60% of the control during the fruit maturation period. During the rest of the year, treatments (d) and (e) received the same amount of water as the control. Irrigation treatment affected both yield and fruit quality. Treatments (b) and (c) decreased the yield by 5% and 15%, respectively (27).

2.2 Irrigation system evaluation.

For irrigation scheduling to be most useful at a specific location, the following should be done:

(1) Evaluation of the irrigation system, determination of application depth and efficiency.

(2) Perform a post-season evaluation to determine changes for next year (5).

The purpose of evaluating irrigation systems is to determine the irrigation system's application efficiency and to find where, why, and to what extent inefficiencies exist in the system, from the water source to the various emission points. Inefficiencies in water application are attributed to non-uniformity of emission at the various emission points (due to pressure variation within the system and manufacturing deficiencies in the equipment), losses of water from the system due to evaporation, leakage from pipes, and deep percolation (28).

Uniformity of water application is the key to high water application efficiency in any kind of irrigation. It is also important to limit the amount of water applied to that which can be stored in the root zone. The efficiency obtained will depend on the spacing of the emitters and the rate of water application relative to the evapotranspiration rate (29).

The average farm irrigation efficiency (FIE) of 1982 / 1983 was 63%; The FIE for the northern part of the Jordan Valley was higher than FIE for the southern part. FIE under drip irrigation was very low at 64%. Citrus FIE value are 84.6 (30).

2.3 Salinity Effects

The long term success of irrigated agriculture depends, on the maintenance of a favorable salt content in the crop root zone. As salts dissolved in the irrigation water are added to the soil, they become concentrated through the evapotranspiration process and eventually their concentration can exceed the tolerance limits of the crop. To prevent yield loss, excess salts must be leached below the root zone by irrigation. Thus, when the net depth of water to be applied is calculated, the salt balance must be considered. Excessive applications of water needed to leach salts away are called leaching requirements (3).

Leaching requirements are defined as the minimum amount of irrigation water supplied that must be drained through the root zone to control soil salinity at a given specific level (31).

Salinity is a major threat to irrigated agriculture because many soils and irrigation waters contain significant amounts of dissolved salts. These salts have limited the crop production on about 25 percent of the irrigated land in the western United States because of the total osmotic effect, individual ion toxicity, and / or reduced soil permeability caused by excess sodium (32).

In sour orange (*Citrus aurantium*) plant growth, leaf water potential, osmotic potential, stomata conductance, and evapotranspiration decreased with increasing NaCl and polyethylene glycol in the nutrient solution (33).

Saline water up to 13 mol Cl m^{-3} primarily influenced tree water uptake and growth of "Shamouti" orange trees, whereas yield was only slightly reduced during six years (34).

Fruit yield of "Verna" lemon trees was progressively decreased by salinity but the effect was influenced by the specific rootstock combination (35).

Results are reported from a long-term field experiment designed to determine the effect of irrigation water salinity on yield and water uptake of mature grapefruit trees. Yield was linearly related to the mean chloride concentration in the soil saturation extract weighted according to determine the effect of irrigation water salinity on yield and water uptake of mature grapefruit trees. Treatments consisted of chloride concentration in the irrigation water of 7.1, 11.4, and 17.1 meq/l added as NaCl+CaCl2 at a 1:1 weight ratio. Total water uptake was reduced with depth and time. There was a 1.45% yield reduction for each 1 meq/l increase in chloride concentration (36).

3- MATERIALS AND METHODS.

3.1 The experiment location

The study was conducted during the 1995 growing season at ARAR farm (Agricultural Unit No. 226, development area 25) located in the central Jordan Valley at latitude 32° 4' N and longitude 35° 35' with an average altitude of 275 meter below Sea level.

3.2 Soil and Irrigation Water Analysis

Undisturbed soil samples for laboratory analysis were collected from three locations representing the experimental area at depths of 0-30, 30-60, 60-90, and 90-120 cm. Samples for chemical properties analysis were collected from three locations as a composite sample at depths of 0-30, and 30-60.

Textural class was determined using the pipette method (37). Soil bulk density was determined using the core method (38). Soil pH was determined for a 1:1 paste by using a pH meter, and electrical conductivity (EC) was determined for the 1:2.5 soil extract (39).

Total nitrogen, available phosphorus, and available potassium were determined by using the Kjeldhal method (40), Oslen method (41), and ammonium acetate method (42), respectively.

Field capacity and permanent wilting point were determined by using the ceramic plate extract method (43) at 0.3, and 15.0 bars vacuum, respectively.

The irrigation water was tested for EC at the beginning of each month during the season. The EC readings were used to determine the leaching requirements for the month.

3.3 Irrigation System

A drip irrigation system was used to apply water. Irrigation water was supplied to the farm by the Jordan Valley Authority twice a week at a rate of 8 liters per second. The system provides 30 liter per hour per emitter when the water pressure is maintained at 1.0 bar. Each plot had two laterals, each lateral had seven emitters of the microsprayer type, therefore each tree had two emitters. Each plot was controlled by a separate valve.

3.3.1 Irrigation System Evaluation

The irrigation system was evaluated for each subunit. The emitters were adjusted and calibrated to give 30 liters per sprayer over a one hour period. Farmer method plots were evaluated without any modifications. Field evaluation data were collected for four rows of trees (two laterals per row of trees); one near the inlet end, one row near the far end, two rows evenly spaced in the middle section. The pressure was measured at the inlet and far end of each lateral. On each lateral, emitter flows were collected for 20 seconds at four different plant locations; at the inlet, 1/3rd of the way down the lateral, 2/3rds down and at the end points of the laterals. The collected flow was measured in a 500 ml graduated cylinder and converted to liters per hour.

- Emission Uniformity (EU) was calculated as (28):

$EU=(q_n / q_a)100$

where:

q_n = The average flow from the lowest one-quarter of the micro sprayers.

q_a = The average flow from all emitters.

- Application efficiency (E_a) was calculated as:

$E_a = EU \times K_s$

where:

EU = Emission uniformity in percent.

K_s = water storage efficiency in percent.

Table : 1 was used to select Ks values (28).

Table 1 Values of Ks for various soils.

Soil Type	K_s(%)
Coarse sand, or light topsoil with gravel subsoil	87
Sands	91
Silts	95
Loam and clays	100

3.4 Irrigation Treatments

The experiment was laid out in a randomized complete block design (RCBD) with four treatments (methods) used to determined the amount of water to be applied. Each treatment was replicated three times within each variety. Figure 1 shows the experimental design layout.

The four irrigation treatment were:

1. Penman-Monteith method: The amount of water to be applied calculated from evapotranspiration computed from climatic data using Penman-Monteith method (T_1).
2. Pan evaporation method: The amount of water to be applied calculated using the evapotranspiration computed from the class- A pan evaporation method (T_2).
3. Hargreaves method: The amount of water to be applied calculated according to the evapotranspiration computed from climatic data using Hargreaves method (T_3).
4. Method that was used by the farmer: In this method water was applied twice a week for two and half hours duration for each application. The same application was given to each crop under consideration. This method was used by the farmer in previous irrigation seasons (T_4).

3.5 Plant Material

Three crops of citrus planted in April 1990, at a spacing of 5.0 meter by 6.0 meter were used, these crops are:

1. Clementine (*Citrus reticulata* Blanco)
2. King (*Citrus nobilis* Lour)
3. Shamouti *(Citrus sinensis (L.)* Osbeck*)*

Each plot size was 35m by 6m containing seven trees (one row). The total tree population was 252 trees for the three crops.

Clementine (V_1)	King (V_2)	Shamouti (V_3)
$T_3R_1V_1$	$T_1R_1V_2$	$T_3R_1V_3$
$T_1R_1V_1$	$T_3R_1V_2$	$T_4R_1V_3$
$T_2R_1V_1$	$T_4R_1V_2$	$T_1R_1V_3$
$T_4R_1V_1$	$T_2R_1V_2$	$T_2R_1V_3$
$T_2R_2V_1$	$T_4R_2V_2$	$T_3R_2V_3$
$T_4R_2V_1$	$T_3R_2V_2$	$T_2R_2V_3$
$T_3R_2V_1$	$T_2R_2V_2$	$T_1R_2V_3$
$T_1R_2V_1$	$T_1R_2V_2$	$T_4R_2V_3$
$T_3R_3V_1$	$T_2R_3V_2$	$T_2R_3V_3$
$T_2R_3V_1$	$T_4R_3V_2$	$T_3R_3V_3$
$T_1R_3V_1$	$T_1R_3V_2$	$T_4R_3V_3$
$T_4R_3V_1$	$T_3R_3V_2$	$T_1R_3V_3$

T_1: Penman Monteith method, T_3: Hargreaves method
T_2: Pan evaporation method, T_4: Farmer method.

Figure 1 Experimental design layout.

3.6 Climatic Data

Ten years (1985-1994) of daily data for maximum temperature (T_{max},°C), minimum temperature (T_{min}°C), maximum relative humidity (RH_{max}%),minimum relative humidity (RH_{min},%), wind velocity (U_2, Km/day), Actual sunshine hours (n hour/day), and pan evaporation (Epan, mm) were collected from the weather station at the University of Jordan experiment station which is representative the experiment area; the weather station is about one kilometer from the experiment area.

Rainfall data collected at the weather station at the University of Jordan Experiment Station during the season (1995) was used for the experiment.

3.7 Citrus Yield

At the end of the season, the yield was obtained by weighing the harvested fruits from the center three trees in each plot.

Water use efficiency (WUE) was determined as:

$$WUE = \frac{Y}{Wa}$$

where :

Y = Total yield of the center three trees of each plot in (Kg).

Wa = Total amount of water applied to the center three trees in (M^3).

3.8 Calculations

For all treatments (T4 treatment) rainfall and irrigation were on the credit side, while soil moisture depletion (Evapotranspiration) was on the debit side. Data on maximum water holding capacity was necessary. Any amount in excess of this capacity was a surplus and will be a deep percolation loss. Evapotranspiration was computed daily from historical climatic data. Penman-Monteith was used in the first treatment (T_1), pan evaporation in the second treatment (T_2), and Hargreaves in the third treatment (T_3). Kc values were taken directly from the literature. Table 2 was used to select the crop coefficient (31).

All plots were irrigated twice a week (fixed irrigation interval) according to the Jordan Valley Authority delivery schedule and lack of pool storage on the farm.

The amount of water applied calculated as (28):

$$GIR = \frac{ETc_d - Pe}{E_a \times (1 - LF)}$$

where:

GIR = Gross irrigation requirements (mm/period).

ETc_d= Crop evapotranspiration under drip irrigation (mm/period).

$ETc_d = ET_p \times Kc \times Kr$

where:

ET_p= Potential evapotranspiration calculated using Penman-Monteith, pan evaporation, or Hargreaves (mm/period).

Kc = Crop Coefficient.

Kr = Reduction factor.

$$Kr = GC + \frac{1}{2}(1 - GC)$$

where:

GC = is the ground cover (the fraction of the total area actually covered by the plant.

Pe = is the effective precipitation (mm) calculated according to the USDA soil conservation service method as (44):

$Pe = P_{tot}(125-0.2\ P_{tot})/125$ for $P_{tot} < 250mm$

$Pe = 125 + 0.1\ P_{tot}$ for $P_{tot} > 250$ mm.

where:

P_{tot} = total preciptation (mm).

E_a = Application efficiency.

LF= Leaching fraction calculated as (45):

$$LF = \frac{EC_w}{2\ Max.\ EC_e}$$

where:

EC_w = Electrical conductivity of the irrigation water mmhos/cm.

Max. EC_e = maximum tolerable electrical conductivity of the soil extract for a given crop.

Table 3 was used to calculated the leaching requirement (45).

Table 2 Kc values for citrus (Grown in a predominantly dry area with light to moderate wind).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tree Providing ≈ 50% ground cover												
Clean cultivated	0.65	0.65	0.60	0.60	0.5	0.55	0.55	0.55	0.55	0.55	0.6	0.6
No weed control	0.9	0.9	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
rees providing ≈ 20% ground cover												
Clean cultivated	0.55	0.55	0.5	0.5	0.5	0.45	0.45	0.45	0.45	0.45	0.5	0.5
No weed control	1.0	1.0	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

Table 3 Salt tolerance level for fruit crops.

Crop	100% Yield		90% Yield		75% Yield		50% Yield		Max. ECe
	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	
Almond	1.5	1.0	2.0	1.4	2.8	1.9	4.1	2.7	7.0
Apple, pear	1.7	1.0	2.3	1.6	3.3	2.2	4.8	3.2	8.0
Apricot	1.6	1.1	2.0	1.3	2.6	1.8	3.7	2.5	6.0
Avocado	1.3	0.9	1.8	1.2	2.5	1.7	3.7	2.4	6.0
Date palm	4.0	2.7	6.8	4.5	10.9	7.3	17.9	12.0	32.0
Fig, Olive	2.7	1.8	3.8	2.6	5.5	3.7	8.4	5.6	14.0
Grape	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12.0
Grapefruit	1.8	1.2	2.4	1.6	3.4	2.2	4.9	3.3	8.0
Lemon	1.7	1.1	2.3	1.6	3.3	2.2	4.8	3.2	8.0
Orange	1.7	1.1	2.3	1.6	3.2	2.2	4.8	3.2	8.0
Peach	1.7	1.1	2.2	1.4	2.9	1.9	4.1	2.7	7.0
Plum	1.5	1.0	2.1	1.4	2.9	1.9	4.3	2.8	7.0
Strawberry	1.0	0.7	1.3	0.9	1.8	1.2	2.7	1.7	4.0

3.9 Calculation of Potential evapotranspiration

3.9.1 Penman-Monteith method

In this method evapotranspiration was computed according to the Penman-Monteith equation as recommended in the FAO Expert Consultation held in May, 1990 in Rome (46). The Penman-Monteith equation consists of two terms: an energy (radiation) term and an aerodynamic (wind and humidity) term. The relative importance of each term varies with climatic conditions. Under windy conditions, particularly in the more arid regions, the aerodynamic term become relatively more important (47).

Required climatic data for this equation are:

Mean temperature (°C), Mean relative humidity (%), total wind velocity (Km/day), and actual sunshine hours (hour/day) The formula used is of the form (46):

$$ET_o = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T+273} U_2 (ea - ed)}{\Delta + \gamma (1 + 0.34 U_2)}$$

where:

ET_o = reference crop evapotranspiration (mm/day).

Rn = Net radiation at the crop surface ($MJ/m^2/day$).

G = Soil heat flux ($MJ/m^2/day$).

T = Average temperature (°C).

U_2 = Windspeed measured at 2m height (m/s).

(ea-ed) = The difference between the saturation vapor pressure at mean air temperature (ea), and the mean actual vapor pressure of air (ed), both in (K Pa).

Δ = Slope of the vapor pressure curve (KPa/°C).

γ = Psychrometric constant (KPa/°C).

When no measured radiation data are available, the net radiation is determined as follows:

$$R_n = R_{ns} - R_{nl}$$

$$R_{ns} = 0.77\ (0.35 + 0.5\frac{n}{N})R_a$$

$$R_{nl} = 2.45\times 10^{-9}\ (0.9\frac{n}{N} + 0.1)(0.34 - 0.14\sqrt{ed})(T_{Kx}^4 + T_{Kn}^4)$$

$$G = 0.14\ (T_a - T_{p3})$$

where:

R_{ns} = Net shortwave radiation (MJ/m^2/day).

R_{nl}= Net longwave radiation (MJ/m^2/day).

R_a = Extraterrestrial radiation (MJ/m^2/day).

n = Actual sunshine hours.

T_{kx} = Maximum temperature in (K°).

T_{kn} = Minimum temperature in (K°).

T_a = Average daily temperature (°C).

T_{p3} = Average temperature for the previous three days (°C).

The saturation vapor pressure (ea) is determined as:

$$e_a = 0.611 \exp\left(\frac{17.27T_a}{T + 237.3}\right)$$

$$e_d = \frac{RH}{100} e_a$$

The slope of the vapor pressure curve, Psychrometric constant, and the atmospheric pressure are determined as (48).

$$\Delta = \frac{4098 e_a}{(T + 237.3)^2}$$

$$\gamma = \frac{CP \times P}{\in \lambda}$$

P = 101.3 - 0.01055 EL

where:

CP = Specific heat constant = 1.013 KJ/Kg/°C.

P = Atmospheric pressure (KPa).

EL = Elevation (m).

λ = Latent heat of vaporization = 2.501-0.002361 T. (MJ/Kg).

$\in$ = Ratio of the molecular weights of the air to water = 0.662.

3.9.2 Class-A Pan Evaporation Method

Evaporation pans provide a measurement of the integrated effects of radiation, wind, temperature, and humidity on evaporation from an open water surface.

Measurements of evaporation can give an indication of plant water use in the field and assist in determining when to irrigate and how much water to apply. Estimations of ET are made using the general equation (31):

$ET_o = K_P\ E_{pan}$.

where:

ET_o = The reference crop evapotranspiration (mm/day)

K_P = the pan coefficient

E_{pan} = class- A pan evaporation (mm)

The K_p value represent an adjustment factor to relate free water loss to crop water loss. The K_p factor depends on the surface conditions around the pan, daily wind run, and relative humidity, see table 4 (30).

The reliability of using evaporation pans depends on the calibration of the pan coefficient with the pan used and its immediate environment.

3.9.3 Hargreaves Method

The modified Hargreaves method, Hargreaves (1985) uses the following equation (3):

$$ET_p = 0.023 \times \sqrt{TD} \times R_a \times (T_a + 17.8)$$

Where:

ET_p = Potential evapotranspiration (mm/day).

T_a = Mean daily temperature in (°C).

R_a = Extraterrestrial radiation (mm/day). Values of Ra depends on the latitude and the month. Monthly values of Ra were taken from FAO paper No 24.

TD = Mean maximum minus mean minimum temperature.

The Hargreaves equation is a good method for areas with air temperature data only. There is little need for local calibration (48).

Table 4 Pan coefficient (K_p) for Class - A Pan for different ground cover and levels of mean relative humidity and 24 hours wind run.

ass-A Pan	Case A: Pan placed in short green cropped area				Case B: Pan Placed in dry fallow area			
H mean%		Low <40	Medium 40-70	High >70		Low <40	Medium 40-70	High >70
ndKm/day	Windward side distance of green crop (m)				Windward side distance of dry fallow (m)			
ht < 175	1	0.55	0.65	0.75	1	0.7	0.8	0.85
	10	0.65	0.75	0.85	10	0.6	0.7	0.8
	100	0.7	0.8	0.85	100	0.55	0.65	0.75
	1000	0.75	0.85	0.85	1000	0.5	0.6	0.7
derate 5-700	1	0.5	0.6	0.65	1	0.65	0.75	0.8
	10	0.6	0.7	0.75	10	0.55	0.65	0.7
	100	0.65	0.75	0.8	100	0.5	0.6	0.65
	1000	0.7	0.8	0.8	1000	0.45	0.55	0.6
ong 5-700	1	0.45	0.5	0.6	1	0.6	0.65	0.7
	10	0.55	0.6	0.65	10	0.5	0.55	0.65
	100	0.6	0.65	0.7	100	0.45	0.5	0.6
	1000	0.65	0.7	0.75	1000	0.4	0.45	0.55
ry strong 00	1	0.4	0.45	0.5	1	0.5	0.6	0.65
	10	0.45	0.55	0.6	10	0.45	0.5	0.55
	100	0.5	0.6	0.65	100	0.4	0.45	0.5
	1000	0.55	0.6	0.65	1000	0.35	0.4	0.45

4. RESULTS AND DISCUSSION

4.1 Soil and irrigation water analysis

4.1.1 Soil analysis

Selected soil physical and chemical properties are presented in Tables 5 and 6. These properties include bulk density, field capacity, permanent wilting point, mechanical analysis, soil electrical conductivity, soil pH, total nitrogen, available phosphorus, and available potassium.

The textural classes were loam for the depths 0-30 and 30-60, and sandy loam for the depths 60-90 and 90-120cm.

Table 5 Soil physical properties

Soil depth (cm)	Bd (1)	FC (2)	pwp (3)	Mechanical analysis			Textural class
				Sand %	Silt %	Clay%	
0-30	1.58	18.49	11.69	59.27	21.94	18.79	loam
30-60	1.60	14.88	8.96	60.90	19.71	19.39	loam
60-90	1.65	13.86	8.09	66.18	22.61	11.21	Sandy loam
90-20	1.52	10.94	5.97	66.92	22.78	10.30	Sandy loam

(1) Bulk density (g/cm^3) **(2) Field capacity (Pv%)**
(3) Permanent wilting point (Pv%)

Table 6 Soil chemical properties.

Soil depth (cm)	EC (1)	pH (2)	N% (3)	P (4)	K (5)
0-30	2.54	7.5	0.042	42.6	430
30-60	2.63	7.65	0.031	19.3	203

(1) Soil electrical conductivity (mmhos/cm) **(2) Soil pH.**
(3) Total nitrogen (%). **(4) Available phosphorus (ppm).**
(5) Available potassium (ppm).

4.1.2. Irrigation water analysis

Irrigation water was tested for electrical conductivity (EC_w) at the beginning of each month during the season. The EC_w reading along with the maximum tolerable electrical conductivity of the soil extract for citrus without yield reduction were used to determine the leaching requirements for the month. The change in irrigation water quality was negligible through the season. Irrigation water quality used did not change greatly during most of the season.

The EC_w value, according to the FAO guidelines for evaluation of water for irrigation, indicate that the irrigation water requires slight to moderate restrictions in use for irrigation. Citrus is reported to be specifically sensitive to moderate concentrations of chloride and sodium in the irrigation water; the use of saline water requires special irrigation management. The leaching requirement should be included in the gross quantity of irrigation water applied, as in the experiment condition. Table 7 and Figure 2 shows the values of EC_w and leaching requirements for each month.

4.2 Climatic data

Ten years (1985-1994) daily climatic data for maximum temperature (Tmax, °C), minimum temperature (Tmin, °C), maximum relative humidity (RH_{max}, %), minimum relative humidity (RH_{min}, %), wind velocity (U2, Km/day), actual sunshine hours (n, hour/day), pan evaporation (E_{pan}, mm), and rainfall data collected during the 1995 growing season at the University of Jordan experiment station weather station were used in the experiment to calculate irrigation requirements for the three varieties of citrus under consideration.
A summary of the climatic data are presented in Appendix 1.

4.3 Effect of irrigation treatments on citrus yield

Yield as affected by irrigation treatment are presented in Tables 7, 8, and 9 for Clementine, King, and Shamouti, respectively.

Table 7 The effect of irrigation treatment on Clementine yield.

Treatment	Scheduling method	GIR[1] m^3/ha	Yield ton/ha
T_1	Penman-Monteith	2681.6 b	14.93 a
T_2	Pan evaporation	3427.2 b	19.41 a
T_3	Hargreaves	2966.4 b	17.49 a
T_4	Farmer method	9430.4 a	20.91 a

Numbers followed by different letters differ significantly at the 5% level according to Duncans multiple range test.
1. Total gross irrigation water applied during the season.

Table 8 The effect of irrigation treatment on king yield.

Treatment	Scheduling method	GIR[1] m^3/ha	Yield ton/ha
T_1	Penman-Monteith	5241.6 d	37.37 a
T_2	Pan evaporation	6739.2 b	38.68 a
T_3	Hargreaves	5776.0 c	32.21 a
T_4	Farmer method	10304.0 a	42.28 a

Numbers followed by different letters differ significantly at the 5% level according to Duncan's multiple range test

1. Total gross irrigation water applied during the season.

Table 9 The effect of irrigation treatments on Shamouti yield .

Treatment	Scheduling method	GIR[1] m^3/ha	Yield ton/ha
T_1	Penman-Monteith	2886.4 b	5.97 a
T_2	Pan evaporation	3715.2 b	8.53 a
T_3	Hargreaves	3196.8 b	4.05 a
T_4	Farmer method	6550.4 a	4.80 a

Numbers followed by different letters differ significantly at the 5% level according to Duncan's multiple range test.

1. Total gross irrigation water applied during the season.

Analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) were used in the SAS program as a means separation to study the differences in yield between the four irrigation treatments for the three citrus crops. The statistical analysis indicated that there were no significant differences in yield between the four irrigation treatments for the three citrus crops. However amount of water applied to Clementine and Shamouti under treatment T_4 was significantly higher than the amounts of water applied under the other irrigation treatments.

For King the results indicated that there were significant differences in the amount of water applied between the four irrigation treatments, the greatest amount of water was applied using the farmer method.

From these results, yield increased with increasing amounts of applied water. This increase was not significant in comparison with the significant increase in the amounts of water applied, which were significantly higher in T_4 than T_1, T_2, and T_3 for all three citrus crops.

Since there were no significant differences in fruit yield between the four irrigation treatments, T_1 , T_2, and T_3 are considered the best treatments with minimum amount of water applied and can be used to schedule irrigations that save water..

From T_1 to T_4 yield was increased by 40.1% with a 251.6% increase in the amount of water applied to the variety Clementine. The 251.6% saving of water was greater than the 40.1% reduction in Clementine yield. From T_1 to T_4 yield increased by 13.1% with a 96.6% increase in the amount of water applied to the variety "King".

The 96.6% saving of water was greater than the 13.1% reduction in King yield. The yield was decreased by 19.6% from T_1 to T_4 with a 126.9% increase in the amount of water applied to the variety Shamouti. The 126.9% saving of water between treatments T_1 and T_4 for Shamouti gives higher yields by about 24.4%.

These results indicated that the farmer applied more water than the plants needed and high amounts of unproductive water were lost from T_4 plots during the irrigation season, both, by percolation below the root zone and evaporation from the soil surface because surface ponding was observed for a longer periods than the other treatments in each irrigation.

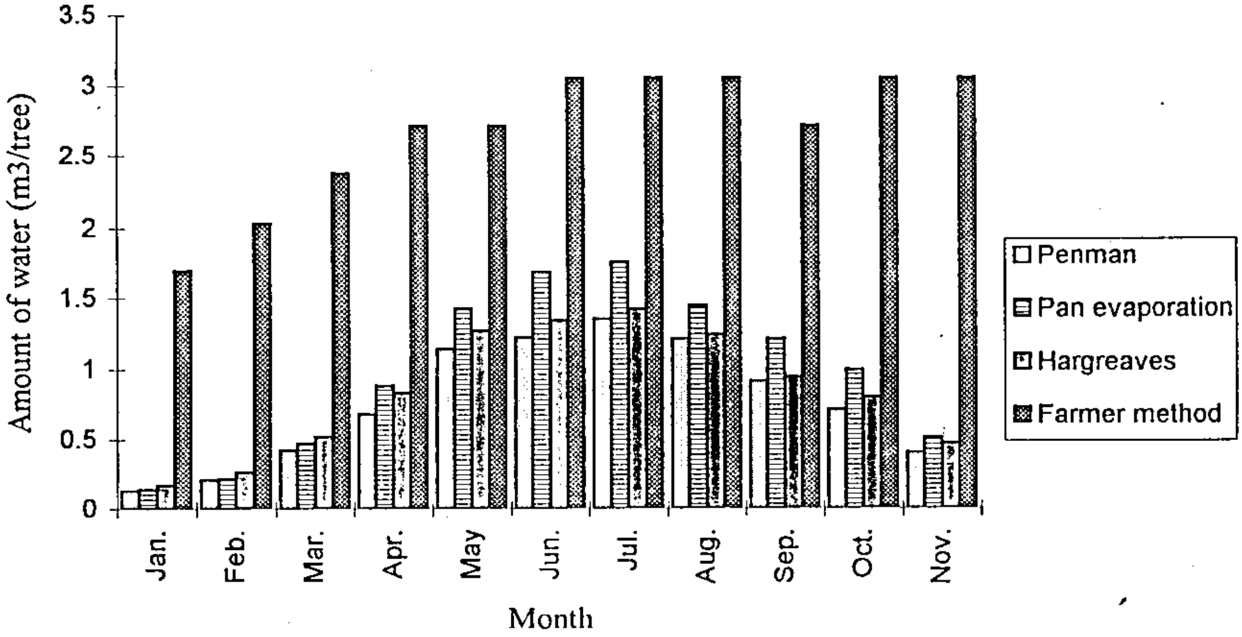

Figure 3 Monthly amount of water applied to Clementine by irrigation treatment (m3/tree).

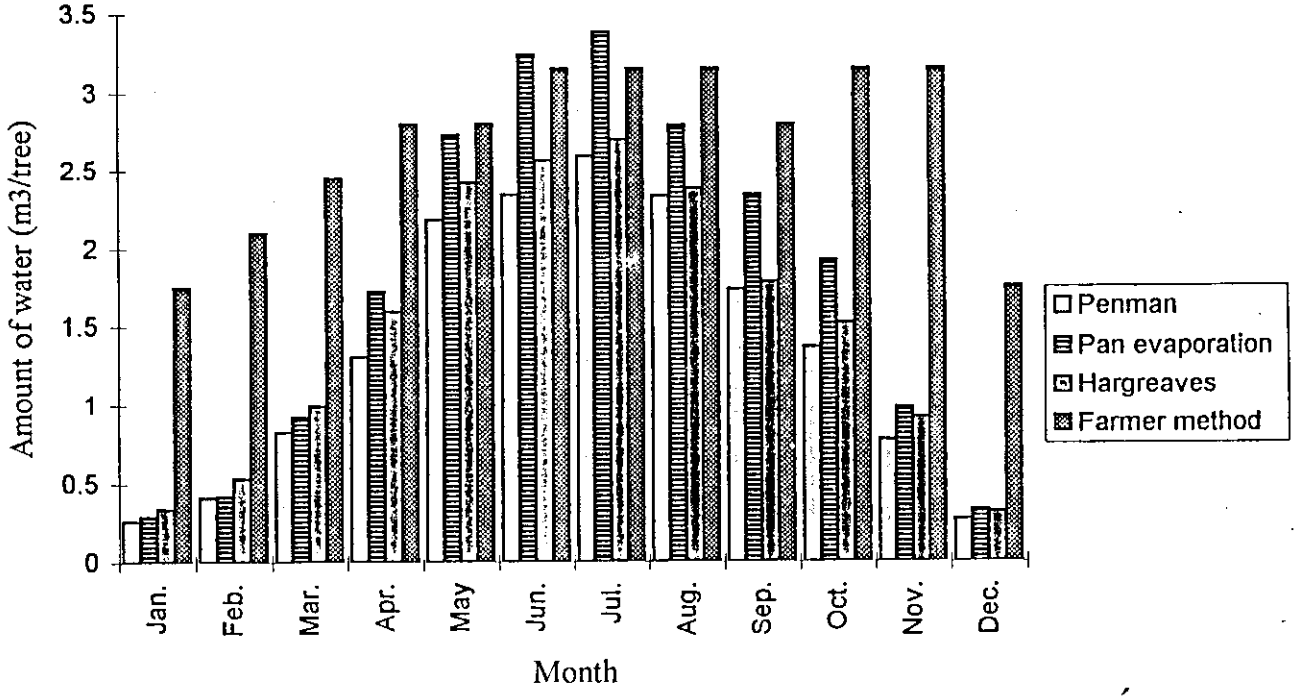

Figure 4 Monthly amount of water applied to King by irrigation treatment (m3/tree)

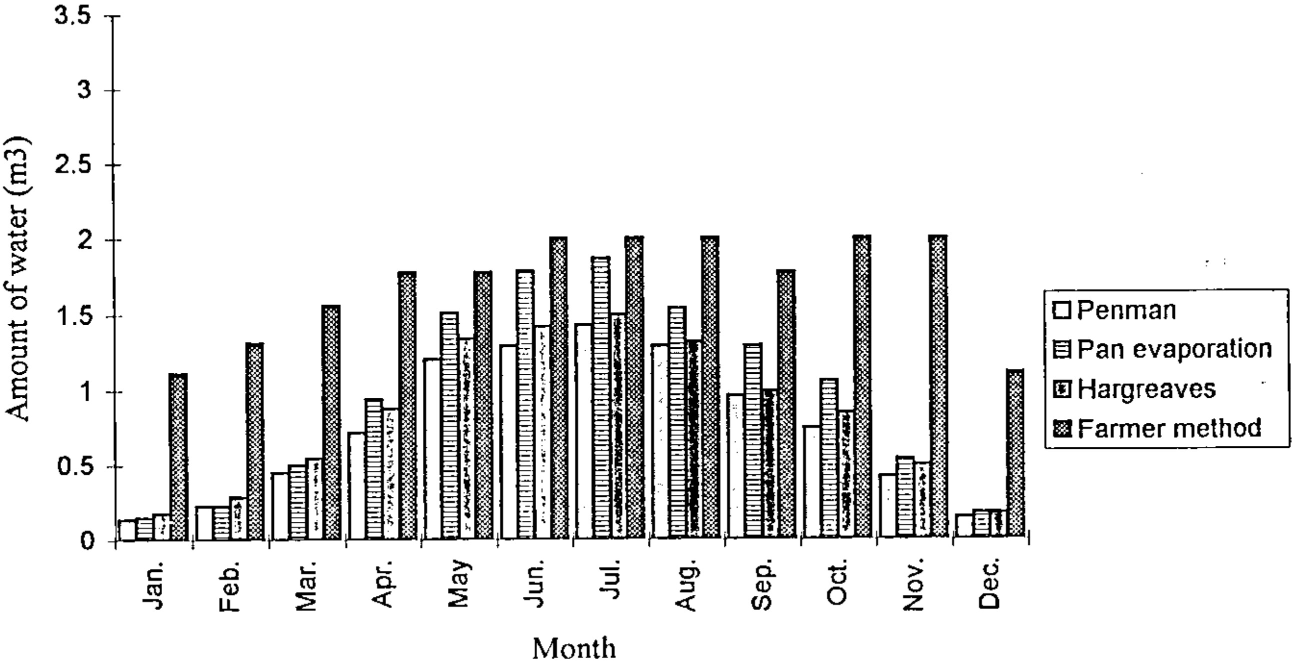

Figure 5 Monthly amount of water applied to Shamouti by irrigation treatment (m3/tree).

4.4 The effect of irrigation treatment on water use efficiency

Water use efficiency (WUE) is defined as the yield of marketable fruit production per unit of water applied per unit area. Average water use efficiencies are presented in Table 10.

Table 10 The effect of irrigation treatments on water use efficiency for the three citrus crops.

Treatment	Scheduling method	WUE (kg/m^3)		
		Clementine	King	Shamouti
T_1	Penman-Monteith	5.57a	7.13a	2.07a
T_2	Pan evaporation	5.66a	5.74ab	2.30a
T_3	Hargreaves	5.90a	5.58ab	1.27a
T_4	Farmer method	2.22 b	4.10b	0.73a

Statistical analysis indicated that water use efficiency for Clementine under treatment T_4 (Farmer method) was significantly lower than WUE obtained from the other irrigation treatments. For King the WUE was significantly lower in T_4 than the WUE value obtained from the T_1 treatment, but there were no significant differences in WUE between T_2, T_3 , and T_4.

For the Shamouti there was no significant differences in WUE between the four irrigation treatments.

The results indicated that water use efficiency increased as water applied decreased. Total fruit production per unit of irrigation water applied also increased with reduced water applications. The greater water use efficiency values were obtained in plots receiving reduced water applications. These plots were T_3 for Clementine, T_1 for King, and T_2 for Shamouti. These values can be ascribed to the reduction of unproductive water losses, both by percolation below the root zone and evaporation from the soil surface.

4.5 Calculation of evapotranspiration

Knowledge of evapotranspiration is essential for estimating irrigation water requirements and scheduling irrigations. Precise irrigation scheduling is particularly important under arid conditions like Jordan where water resources are limited.

Using Penman-Monteith, pan evaporation, and Hargreaves methods, daily values of reference evapotranspiration (ET_p) were computed from the ten years (1985-1994) climatic data observed at the University of Jordan Experiment station weather station.

The daily values of potential evapotranspiration were multiplied by the crop coefficient (k_c) values for citrus obtained from Doorenbos and Pruitt (1977) for each month to get citrus evapotranspiration (ET_c). The ET_c was multiplied by the reduction factor (Kr) to relate crop evapotranspiration under convential irrigation methods to the crop evapotranspiration under drip irrigation (ET_{cd}). Kr values were 0.6 for Clementine and Shamouti and 0.75 for King; the difference depends on plant ground cover. The seasonal values of ET_{cd} were 864.8, 1099.3, and 961.6 mm using Penman-Monteith, Pan evaporation, and Hargreaves methods, respectively, for Clementine and Shamouti, and 967.6, 1229.9, and 1076.0 mm using Penman-Monteith, Pan evaporation, and Hargreaves methods, respectively, for

King. Seasonal ET_{cd} values for King were higher than seasonal values for Clementine and Shamouti. "King" has about 50% ground cover, while Clementine and Shamouti has about 20% ground cover. K_r for King is higher than K_r for Clementine and Shamouti and the ET_{cd} value is higher for King than for Clementine and Shamouti

Monthly values of ET_{cd}, K_c, ET_c, K_r and ET_{cd} are presented in Tables 11,12, 13, 14, 15, and 16 and Figures 5 and 6.

Table 11 Monthly Clementine and Shamouti evapotranspiration calculated according to the Penman-Monteith method (mm).

Month	ET_p	K_c	ET_c	K_r	ET_{cd}
Jan.	44.87	1.0	44.87	0.60	26.92
Feb.	54.86	1.0	54.86	0.60	32.92
Mar.	93.20	0.95	88.54	0.60	53.12
Apr.	132.85	0.95	126.21	0.60	75.72
May	185.34	0.95	176.07	0.60	105.64
June	197.16	0.95	187.30	0.60	112.38
July	216.04	0.95	205.24	0.60	123.14
Aug.	201.62	0.95	191.54	0.60	114.92
Sep.	160.89	0.95	152.85	0.60	91.71
Oct.	113.02	0.95	107.37	0.60	64.42
Nov.	67.23	0.95	63.87	0.60	38.32
Dec.	44.81	0.95	42.57	0.60	25.54
Total	1551.89		1441.29		864.77

ET_p: **Potential evapotranspiration.**

ET_c: **Crop evapotranspiration.**

ET_{cd}: **Crop evapotranspiration under drip irrigation.**

K_c: **Crop Coefficient.**

K_r: **Reduction factor.**

Table 12 Monthly Clementine and Shamouti evapotranspiration calculated according to the pan evaporation method (mm).

Month	ET_p	K_c	ET_c	K_r	ET_{cd}
Jan.	47.77	1.0	47.77	0.60	28.66
Feb.	53.92	1.0	53.92	0.60	32.35
Mar.	102.87	0.95	97.73	0.60	58.64
Apr.	175.01	0.95	166.26	0.60	99.67
May	232.10	0.95	220.50	0.60	132.30
June	272.46	0.95	258.84	0.60	155.30
July	280.89	0.95	266.85	0.60	160.11
Aug.	241.68	0.95	229.60	0.60	137.76
Sep.	215.48	0.95	204.71	0.60	122.83
Oct.	160.23	0.95	152.22	0.60	91.33
Nov.	84.62	0.95	80.39	0.60	48.23
Dec.	56.19	0.95	53.38	0.60	32.03
Total	1923.22		1832.17		1099.30

ET_p: **Potential evapotranspiration.**

ET_c: **Crop evapotranspiration.**

ET_{cd}: **Crop evapotranspiration under drip irrigation.**

K_c: **Crop Coefficient.**

K_r: **Reduction factor.**

Table 13 Monthly Clementine and Shamouti evapotranspiration calculated according to the Hargreaves method (mm).

Month	ET_p	K_c	ET_c	K_r	ET_{cd}
Jan.	57.99	1.0	57.99	0.60	34.79
Feb.	68.05	1.0	68.05	0.60	40.83
Mar.	111.47	0.95	105.90	0.60	63.54
Apr.	162.22	0.95	154.11	0.60	92.47
May	202.10	0.95	192.0	0.60	115.20
June	217.21	0.95	206.35	0.60	123.81
July	224.99	0.95	213.74	0.60	128.24
Aug.	206.92	0.95	196.57	0.60	117.94
Sep.	167.62	0.95	159.24	0.60	95.54
Oct.	126.66	0.95	120.33	0.60	72.20
Nov.	79.22	0.95	75.26	0.60	45.16
Dec.	55.95	0.95	53.15	0.60	31.89
Total	1680.40		1602.69		961.61

ET_p: **Potential evapotranspiration.**
ET_c: **Crop evapotranspiration.**
ET_{cd}: **Crop evapotranspiration under drip irrigation.**
K_c: **Crop Coefficient.**
K_r: **Reduction factor.**

Table 14 Monthly King evapotranspiration calculated according to the Penman-Monteith method (mm).

Month	ET_p	K_c	ET_c	K_r	ET_{cd}
Jan.	44.87	0.90	40.38	0.75	30.29
Feb.	54.86	0.90	49.37	0.75	37.03
Mar.	93.20	0.85	79.22	0.75	59.42
Apr.	132.85	0.85	112.92	0.75	84.69
May	185.34	0.85	157.54	0.75	118.16
June	197.16	0.85	167.59	0.75	125.69
July	216.04	0.85	183.63	0.75	127.72
Aug.	201.62	0.85	171.38	0.75	128.54
Sep.	160.89	0.85	136.76	0.75	102.57
Oct.	113.02	0.85	96.07	0.75	72.05
Nov.	67.23	0.85	57.15	0.75	42.86
Dec.	44.81	0.85	38.09	0.75	28.57
Total	1511.89		1290.10		967.59

ET_p: **Potential evapotranspiration.**

ET_c: **Crop evapotranspiration.**

ET_{cd}: **Crop evapotranspiration under drip irrigation.**

K_c: **Crop Coefficient.**

K_r: **Reduction factor.**

Table 15 Monthly King evapotranspiration calculated according to the pan evaporation method (mm).

Month	ET_p	K_c	ET_c	K_r	ET_{cd}
Jan.	47.77	0.90	42.99	0.75	32.24
Feb.	53.92	0.90	48.53	0.75	36.40
Mar.	102.87	0.85	87.44	0.75	65.58
Apr.	175.01	0.85	148.76	0.75	111.57
May	232.10	0.85	197.29	0.75	147.97
June	272.46	0.85	231.59	0.75	173.69
July	280.89	0.85	238.76	0.75	179.07
Aug.	241.68	0.85	205.43	0.75	154.07
Sep.	215.48	0.85	183.16	0.75	137.37
Oct.	160.23	0.85	136.20	0.75	102.15
Nov.	84.62	0.85	71.93	0.75	53.95
Dec.	56.19	0.85	47.76	0.75	35.82
Total	1923.22		1639.84		1229.88

ET_p: **Potential evapotranspiration.**

ET_c: **Crop evapotranspiration.**

ET_{cd}: **Crop evapotranspiration under drip irrigation.**

K_c: **Crop Coefficient.**

K_r: **Reduction factor.**

Table 16 Monthly King evapotranspiration calculated according to the Hargreaves method (mm).

Month	ET_p	K_c	ET_c	K_r	ET_{cd}
Jan.	57.99	0.90	52.19	0.75	39.14
Feb.	68.05	0.90	61.25	0.75	45.94
Mar.	111.47	0.85	94.75	0.75	71.06
Apr.	162.22	0.85	137.89	0.75	103.42
May	202.10	0.85	171.79	0.75	128.84
June	217.21	0.85	184.63	0.75	138.47
July	224.99	0.85	191.24	0.75	143.43
Aug.	206.92	0.85	175.88	0.75	131.91
Sep.	167.62	0.85	142.48	0.75	106.86
Oct.	126.66	0.85	107.66	0.75	80.75
Nov.	79.22	0.85	67.34	0.75	50.51
Dec.	55.95	0.85	47.56	0.75	35.67
Total	1680.40		1434.66		1076.0

ET_p : **Potential evapotranspiration.**

ET_c : **Crop evapotranspiration.**

ET_{cd} : **Crop evapotranspiration under drip irrigation.**

K_c : **Crop Coefficient.**

K_r : **Reduction factor.**

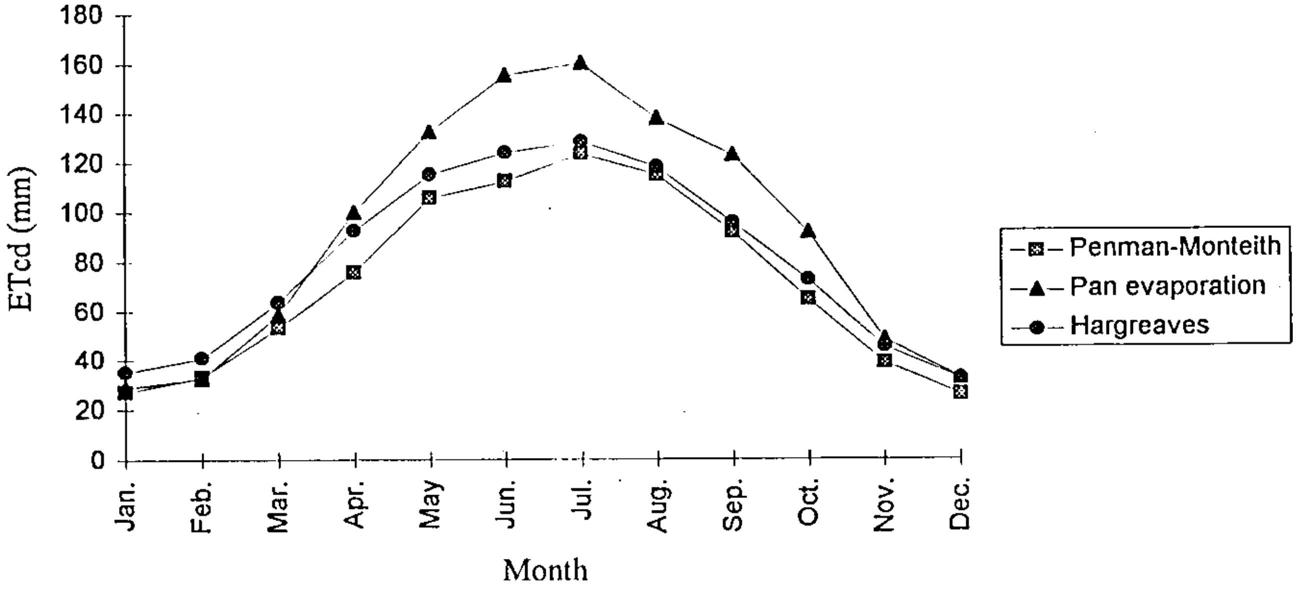

Figure 6 Monthly Clementine and Shamouti evapotranspiration calculated according to the Penman-Monteith, Pan evaopration, and Hargreaves methods.

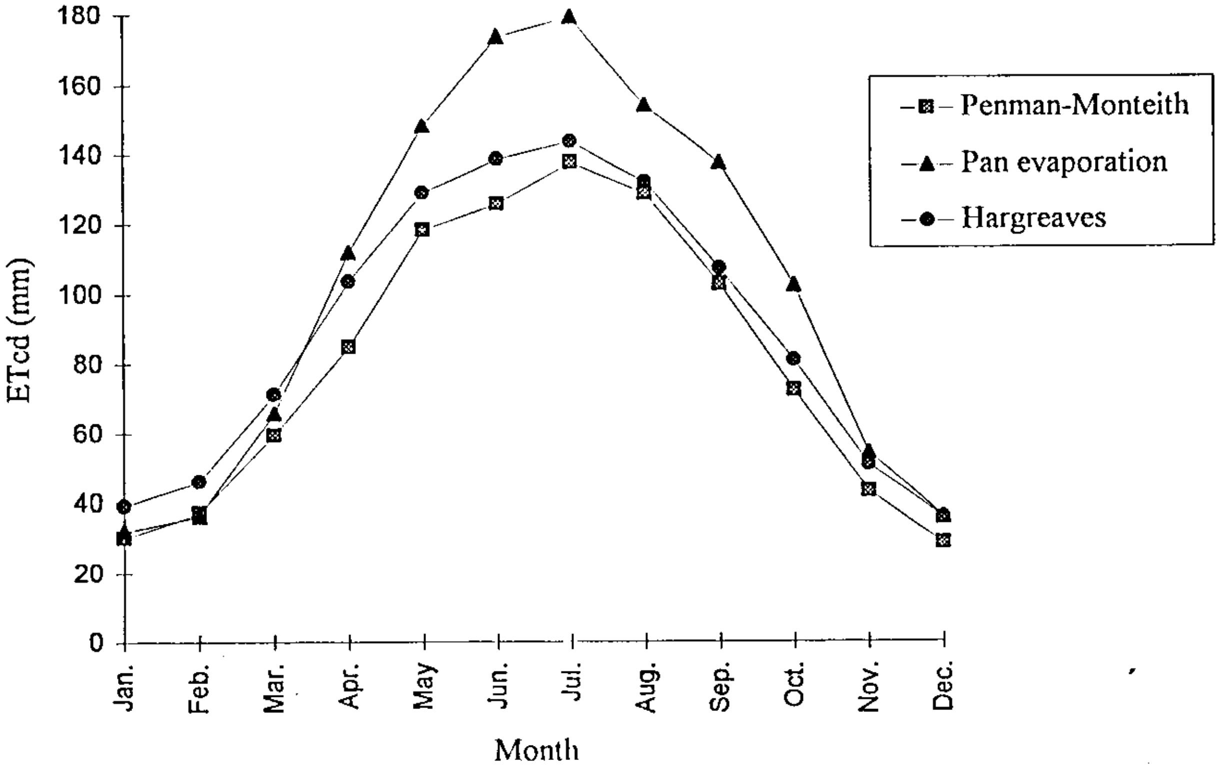

Figure 7 Monthly King evapotranspiration calculated according to the Penman-Monteith, Pan evaporation, and Hargreaves methods.

4.6 Irrigation system evaluation

An evaluation was made for each subunit under initial and adjustment conditions. There were five subunits used in the treatments, two planted with Clementine, two planted with King and one subunit planted with Shamouti. There are two laterals per row of trees, each row consists of seven trees with one microsprayer emitter per tree per lateral line (two sprayers per tree). Under the initial condition the system was evaluated without any modifications. Under the adjustment condition each emitter was adjusted and calibrated to give 30 liters over a one hour period, 60 liters total per tree. Farmer method plots (T_4) were evaluated separately without any modification to estimate the discharge of each emitter. There are nine farmer method plots, three for each variety.

Field evaluation data is shown in Appendix 2.

In the initial condition the emission uniformity (EU) values were 55.8%, 64.7%, 68.1%, 62.6%, and 73.9% for subunits 1, 2, 3, 4, and 5 respectively.

Application efficiency (Ea) was calculated by multiplying the emission uniformity by the storage efficiency obtained from table 1 depending on the soil texture. Ea values under the initial condition were 50.7%, 58.9%, 62%, 57% and 67.2% for subunits 1, 2, 3, 4, and 5 respectively. These values are unacceptable and indicate that the system is not working properly, trees are not receiving the same amounts of irrigation water, and there may be significant quantities of irrigation water lost to deep percolation.

In the adjustment case the EU values were 93.8%, 91.5%, 90.2%, 89%, and 87% for subunits 1, 2, 3, 4, and 5 respectively. Ea values were 85%, 83%, 82%, 81%, and 79% for subunits 1, 2, 3, 4, and 5 respectively. These values are excellent and indicate that the trees are receiving approximately the same amounts of irrigation water and there is potential for little wastage of irrigation water.

5- SUMMARY AND CONCLUSION

A study was carried out during the 1995 growing season at ARAR farm located in the central Jordan Valley to examine the possibility of saving water by scheduling irrigation on scientific basis using Penman-Monteith, Pan evaporation, and Hargreaves.

Four irrigation treatments were used to irrigate three citrus crops. These crops are Clementine, King, and Shamouti.

The four irrigation treatments used were as follows:

(1) Penman-Monteith method (T_1): The amount of water to be applied calculated according to the evapotranspiration computed from climatic data using Penman-Monteith method.

(2) Pan evaporation method (T_2): The amount of water to be applied calculated according to the evapotranspiration computed by using class-A pan evaporation.

(3) Hargreaves method (T_3): The amount of water to be applied calculated according to the evapotranspiration computed from climatic data using Hargreaves methods.

(4) Farmer method (T_4): In this method water was applied twice a week for two and half hours duration each irrigation.

The experiment was laid out in a randomized complete block design and each treatment was replicated three times within each citrus crop. Each plot size was 35m by 6m containing seven trees (one row).

The results showed the following:

(1) The average yield was 14.93, 19.41 , 17.49 , and 20.91 tons per hectare under T_1 , T_2 , T_3 and T_4, respectively for the first crop Clementine, and 37.37, 38.68, 32.21, and 42.28 tons per hectare under T1, T2, T3, and T4, respectively for King, and 5.97, 8.53, 4.05 and 4.80 tons per hectare for Shamouti. No significant differences in fruit yield between the four irrigation treatments within the three citrus crops.

(2) The total amount of water applied to Clementine during the season were 2681.6, 3427.2, 2966.4, and 9430.4 M^3 per hectare for T_1, T_2, T_3, and T_4 treatments respectively, 5241.6, 6739.2, 5776.0, and 10304 M^3 per hectare applied to the King under T_1, T_2, T_3 and T_4 respectively, and 2886.4, 3715.2, 3196.8 and 6550.4 M^3 per hectare applied to the "Shamouti" under T_1, T_2, T_3 and T_4 respectively. The amount of water applied according to T_4 (farmer method) was significantly higher than the amount of water applied according to the other irrigation treatments within the three citrus crops.

(3) The average values of water use efficiency for Clementine were 5.57, 5.66, 5.90, and 2.22 Kg per M^3 under T_1, T_2, T_3 and T_4, respectively, 7.13, 5.74, 5.58, and 4.1 Kg per M^3 under T_1, T_2, T_3 and T_4, respectively for King, and 2.07 , 2.30 , 1.27 , and 0.73 Kg per M^3 under T_1, T_2, T_3, and T_4, respectively for Shamouti. The water use efficiency values of T4 (farmer method) were significantly lower than the water use efficiency values obtained from the other irrigation treatments in Clementine and

King and there were no significant differences in WUE between the four irrigation treatments in Shamouti.

The following can be concluded:

(1) The farmer applied more water than the plant needed and high amounts of unproductive water were lost both by percolation below the root zone and evaporation from the soil surface.

(2) Scheduling irrigation on scientific basis using Penman-Monteith, Pan evaporation, and Hargreaves found to be the best scheduling with minimum amount of water applied and could be used to save considerable amounts of water.

(3) Penman-Monteith is considered as the best for use by researchers because it is include most of the climatic data.

(4) Hargreaves are considered the best for use by the farmer or researchers when minimum climatic data are available.

(5) Pan evaporation can be used for scheduling irrigation when climatic data are not available.

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APPENDIX 1

CLIMATIC DATA

JANUARY

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	18.9	8.9	74	55	58	5.0	1.6	0.0
2	17.6	9.3	75	58	74	4.4	1.7	0.0
3	17.9	9.4	78	63	80	4.3	1.6	0.0
4	17.2	8.9	80	65	60	5.3	1.4	1.0
5	17.7	7.7	83	52	49	5.3	1.1	0.0
6	18.1	8.4	80	57	70	4.8	1.4	5.0
7	19.1	9.0	71	51	66	7.5	2.1	8.0
8	18.6	8.0	73	53	54	5.8	1.6	0.0
9	18.9	8.0	74	51	89	7.0	2.2	0.0
10	18.7	8.6	74	53	85	5.3	2.7	0.0
11	19.0	9.4	71	49	76	6.3	2.4	0.5
12	18.9	9.1	70	52	111	5.1	2.0	1.0
13	18.8	10.3	77	55	83	4.1	1.5	0.0
14	19.1	10.1	77	57	55	4.8	1.4	0.0
15	18.1	9.7	82	64	52	4.2	1.7	0.0
16	17.8	9.0	79	62	45	4.2	1.8	0.0
17	18.1	8.1	76	51	40	6.6	1.8	1.4
18	19.6	8.7	73	46	62	7.1	2.3	22.0
19	19.7	8.7	69	45	53	6.2	1.9	35.0
20	18.9	8.6	78	54	47	4.5	1.8	0.0
21	17.3	8.8	78	60	49	3.5	1.5	0.0
22	17.0	9.4	90	60	47	3.1	1.2	0.0
23	18.2	8.6	85	58	67	6.3	1.5	0.7
24	17.5	7.8	80	55	82	4.3	1.9	2.6
25	18.1	8.6	72	60	76	5.8	1.6	0.0
26	17.8	8.1	76	54	66	5.4	2.0	0.0
27	18.6	7.3	77	47	86	6.4	2.4	0.0
28	19.1	9.0	70	48	59	6.7	2.2	0.0
29	20.0	8.4	75	45	39	7.9	1.8	0.0
30	19.5	8.4	82	50	58	6.4	2.1	0.0
31	19.5	9.1	71	48	96	5.7	2.2	0.0

FEBRAUARY

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	16.7	8.6	80	62	91	3.0	1.3	0.0
2	16.9	8.2	82	62	71	4.6	1.8	0.0
3	18.2	9.1	79	51	88	4.9	2.0	0.0
4	18.2	8.8	72	53	75	6.1	2.0	15.5
5	19.2	8.3	74	48	79	7.0	2.0	1.0
6	18.6	9.3	72	52	61	5.5	1.7	0.0
7	19.1	8.5	77	50	49	5.9	2.2	7.0
8	19.2	8.7	81	48	53	5.7	1.9	3.0
9	17.5	8.4	79	57	64	6.3	1.7	0.0
10	18.7	7.6	82	52	56	7.1	2.3	0.0
11	18.9	8.3	84	54	62	7.6	2.2	0.0
12	19.3	9.3	78	48	60	7.4	2.8	0.0
13	20.3	10.1	74	50	61	6.3	2.8	0.0
14	19.9	9.5	78	50	66	6.9	2.2	0.0
15	20.7	9.5	78	52	79	6.8	2.1	3.0
16	19.7	10.6	75	47	67	6.4	2.6	0.0
17	20.7	10.4	73	49	48	6.0	2.2	0.0
18	19.7	8.9	80	50	45	7.1	2.0	0.0
19	21.2	8.9	71	44	54	7.9	2.6	0.0
20	20.9	9.0	74	47	59	8.2	2.7	0.0
21	20.7	9.0	77	45	54	7.3	2.8	0.0
22	21.8	10.1	72	48	63	6.5	2.8	0.0
23	20.0	10.0	74	51	67	5.9	2.5	0.0
24	20.3	9.3	76	50	62	6.1	2.8	0.0
25	19.8	9.7	76	52	72	6.8	2.3	0.0
26	20.3	9.5	75	57	70	5.5	2.4	0.0
27	20.0	9.3	78	54	45	5.3	2.6	0.0
28	21.0	10.1	82	54	56	6.6	2.5	0.0

MARCH

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	20.8	9.8	70	45	62	6.4	2.7	0.0
2	22.0	9.7	75	46	81	8.2	3.3	0.0
3	22.0	10.1	72	45	64	8.4	3.9	0.0
4	22.0	10.0	70	48	74	6.2	3.3	0.0
5	21.4	10.8	75	55	72	7.0	2.8	0.0
6	20.5	11.0	73	48	74	5.0	3.1	0.0
7	21.1	11.0	76	50	67	6.8	3.2	0.0
8	22.3	10.1	70	42	80	8.4	3.7	0.0
9	22.7	10.4	65	39	80	7.2	5.6	0.0
10	22.6	11.7	64	41	69	7.0	5.0	0.0
11	21.3	10.7	64	45	79	6.1	2.8	0.0
12	22.6	10.6	71	46	85	7.9	3.8	0.0
13	21.0	11.2	71	52	92	4.6	3.5	0.0
14	21.4	11.2	76	50	77	5.8	3.1	0.0
15	21.7	10.1	77	48	83	7.2	2.9	0.0
16	24.0	10.2	75	42	96	7.9	4.0	10.5
17	24.6	11.5	63	38	73	8.4	4.3	0.0
18	23.5	12.0	71	44	57	8.0	2.9	0.0
19	23.9	12.2	74	43	90	8.8	4.1	0.0
20	23.8	11.8	70	41	100	7.6	4.2	0.0
21	23.7	11.7	67	43	68	6.8	3.6	0.0
22	23.8	11.9	70	51	85	6.3	3.8	0.0
23	25.4	12.8	71	47	83	6.5	4.2	0.0
24	24.8	13.3	74	47	81	6.6	4.2	3.0
25	25.3	13.4	75	44	74	8.5	4.4	1.0
26	25.3	12.8	74	46	69	9.1	4.6	0.0
27	27.6	13.1	70	38	64	9.2	5.4	0.0
28	28.1	13.5	67	39	76	8.8	4.5	0.0
29	27.6	14.2	66	36	85	10	5.4	0.0
30	26.2	12.8	62	41	77	8.1	4.4	0.0
31	25.9	13.5	69	41	84	7.6	4.3	0.0

APRIL

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	24.9	13.5	76	48	70	6.6	4.6	0.0
2	25.4	13.3	73	46	84	7.1	4.4	3.0
3	26.2	12.6	64	37	79	9.7	5.3	0.0
4	27.7	12.5	69	36	88	8.6	6.6	0.0
5	28.0	13.9	63	39	69	7.9	6.7	0.0
6	28.5	13.7	58	37	74	9.2	5.5	0.0
7	30.2	14.4	60	32	82	8.3	6.2	0.0
8	28.9	15.4	59	32	73	8.1	6.0	0.0
9	29.1	15.1	60	39	66	10.2	6.1	0.0
10	29.7	14.5	60	34	75	8.9	6.3	0.0
11	31.2	15.9	63	32	94	8.9	6.5	0.0
12	31.3	16.5	57	30	96	9.8	6.6	0.0
13	31.6	15.7	58	29	89	10.2	7.0	0.0
14	30.6	16.0	51	34	88	10.0	6.6	0.0
15	31.1	15.3	56	32	57	10.1	6.9	0.0
16	30.9	15.4	50	31	70	9.5	6.9	0.0
17	30.3	15.8	59	33	79	10.0	7.6	0.0
18	32.2	15.6	57	27	88	10.2	8.6	0.0
19	33.6	17.0	48	27	98	10.1	8.1	0.0
20	31.7	18.3	55	34	83	9.5	8.1	0.0
21	32.7	17.0	52	30	85	8.7	8.3	0.0
22	31.6	17.0	49	34	105	7.6	8.3	0.0
23	31.1	17.5	56	38	92	9.3	6.7	0.0
24	32.0	17.4	57	33	91	9.9	7.5	0.0
25	30.9	18.9	54	33	97	9.4	7.9	0.0
26	30.1	16.8	57	37	83	9.0	7.0	0.0
27	31.6	16.5	60	31	88	9.9	7.3	0.0
28	34.5	18.2	57	28	74	10.5	8.5	0.0
29	34.3	18.9	55	30	78	8.0	8.4	0.0
30	33.2	18.5	53	32	93	7.8	6.5	0.0

MAY

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour) (hour/day)	E_{pan} (mm)	Rainfall (mm)
1	28.8	18.3	68	40	111	8.8	6.8	0.0
2	28.9	16.3	61	37	113	10.0	7.4	0.0
3	30.2	14.8	62	35	95	8.8	7.4	0.0
4	31.8	16.7	61	38	112	9.6	8.7	0.0
5	30.3	17.1	62	40	114	10.2	7.6	0.0
6	31.4	16.9	59	32	77	8.6	8.4	0.0
7	34.4	17.4	52	29	112	9.0	8.2	0.0
8	35.0	19.2	51	32	102	9.4	8.3	0.0
9	31.3	19.7	61	40	111	8.1	7.3	0.0
10	31.8	16.6	60	36	111	9.8	8.2	0.0
11	32.0	17.7	59	38	127	8.1	8.1	0.0
12	31.3	17.7	61	37	123	9.0	7.9	0.0
13	32.5	18.7	62	35	123	9.4	8.1	0.0
14	35.7	18.9	55	29	107	10.1	9.5	0.0
15	37.0	22.1	53	30	137	10.1	8.9	0.0
16	36.5	22.3	51	31	117	8.6	9.3	0.0
17	36.3	20.8	55	29	112	10.9	9.7	0.0
18	36.0	20.1	52	27	125	10.9	8.7	0.0
19	37.3	20.1	57	30	132	11.4	9.5	0.0
20	37.0	21.8	53	30	131	11.3	9.2	0.0
21	35.2	21.2	55	32	121	12.0	8.0	0.0
22	34.9	20.6	58	34	125	10.1	9.4	0.0
23	34.9	19.3	59	31	121	11.4	9.0	0.0
24	34.8	19.7	65	32	129	11.7	9.5	0.0
25	36.0	20.6	64	33	110	12.0	9.2	0.0
26	37.3	21.7	53	30	108	11.1	9.2	0.0
27	38.0	21.5	53	30	94	10.4	10.8	0.0
28	38.0	22.8	51	32	120	11.3	10.8	0.0
29	37.7	22.3	53	31	117	11.3	11.5	0.0
30	35.4	22.8	63	40	131	10.5	10.4	0.0
31	36.2	21.1	64	35	102	11.7	9.3	0.0

JUNE

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	36.2	20.6	60	30	133	11.1	9.7	0.0
2	35.5	21.1	59	33	106	10.9	10.6	0.0
3	36.2	21.5	57	32	118	11.0	10.2	0.0
4	36.4	21.5	58	32	120	11.2	10.2	0.0
5	36.6	21.5	56	32	105	11.0	10.7	0.0
6	37.6	21.0	58	29	118	11.5	12.4	0.0
7	37.6	21.7	61	32	113	11.4	11.2	0.0
8	37.2	22.3	61	35	131	11.5	10.5	0.0
9	37.1	21.8	58	33	115	10.4	10.8	0.0
10	38.1	21.9	52	31	108	11.6	11.5	0.0
11	38.0	23.1	54	33	134	10.2	11.3	0.0
12	37.1	22.8	59	34	102	10.3	10.1	0.0
13	37.8	22.9	58	32	93	11.1	10.4	0.0
14	38.8	22.8	56	35	112	10.9	10.8	0.0
15	37.7	23.5	59	35	110	11.0	10.1	0.0
16	36.5	23.7	56	36	103	10.7	10.2	0.0
17	37.4	22.9	61	33	107	11.2	10.8	0.0
18	37.3	22.8	60	36	93	10.9	10.7	0.0
19	37.5	22.8	60	33	116	11.0	10.8	0.0
20	37.5	23.2	63	35	86	10.7	10.7	0.0
21	38.5	23.2	58	35	113	11.2	10.3	0.0
22	39.6	23.5	56	31	122	11.3	11.2	0.0
23	39.0	24.7	52	34	116	11.3	10.8	0.0
24	37.9	24.0	60	38	121	10.8	11.0	0.0
25	38.5	24.0	64	35	113	10.9	9.7	0.0
26	39.0	24.0	60	34	88	11.1	10.4	0.0
27	39.0	23.9	58	32	103	10.6	11.4	0.0
28	38.3	24.3	53	33	102	11.3	11.0	0.0
29	38.3	23.2	57	33	95	11.3	10.6	0.0
30	38.0	23.9	63	36	105	11.6	10.7	0.0

JULY

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	38.2	24.0	62	33	103	11.9	10.0	0.0
2	38.6	23.8	57	33	128	11.9	10.4	0.0
3	38.7	23.6	56	32	124	11.9	10.4	0.0
4	38.7	24.2	55	34	114	12.0	11.0	0.0
5	38.8	24.5	59	36	127	11.9	9.5	0.0
6	38.6	24.6	58	35	115	12.0	10.8	0.0
7	38.8	24.3	57	36	109	12.1	9.9	0.0
8	39.1	24.4	56	32	111	12.2	10.4	0.0
9	39.8	24.7	53	31	122	12.3	10.8	0.0
10	40.1	25.5	58	32	114	12.2	9.8	0.0
11	39.2	25.5	61	32	123	12.5	9.8	0.0
12	39.2	24.4	60	32	108	12.0	11.3	0.0
13	38.7	24.6	58	33	124	12.0	11.6	0.0
14	38.9	25.1	59	35	132	12.4	10.9	0.0
15	39.0	25.2	60	36	134	12.4	10.3	0.0
16	38.9	25.5	61	38	122	11.5	11.3	0.0
17	39.0	25.3	62	35	115	12.3	9.5	0.0
18	39.5	25.2	61	35	115	12.3	10.2	0.0
19	39.4	25.4	56	35	120	12.1	11.3	0.0
20	39.0	25.0	59	35	114	11.9	11.2	0.0
21	39.0	24.9	61	35	110	12.3	10.4	0.0
22	39.8	25.2	62	34	115	12.0	10.9	0.0
23	39.8	25.8	62	37	120	12.0	11.2	0.0
24	39.8	25.4	66	34	112	12.6	11.6	0.0
25	39.3	25.2	58	34	106	12.3	9.2	0.0
26	40.0	25.8	60	36	120	12.4	10.6	0.0
27	40.3	26.4	63	33	125	12.5	10.9	0.0
28	40.6	25.5	60	34	113	12.5	12.4	0.0
29	39.3	24.8	61	35	117	12.0	12.1	0.0
30	38.4	25.7	60	37	107	12.2	10.6	0.0
31	38.4	26.2	66	39	118	11.9	10.5	0.0

AUGUST

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	38.6	25.5	60	38	102	12.0	9.3	0.0
2	39.3	25.7	62	37	107	11.7	8.9	0.0
3	39.7	25.2	62	36	102	11.8	8.9	0.0
4	40.0	25.5	64	37	114	11.9	9.5	0.0
5	39.6	26.0	64	40	103	11.9	9.6	0.0
6	38.9	25.5	62	38	103	11.6	9.9	0.0
7	39.7	25.2	64	37	115	12.0	9.3	0.0
8	39.8	25.7	60	34	111	11.8	9.9	0.0
9	39.5	25.7	62	34	108	12.1	9.3	0.0
10	39.5	25.5	61	33	107	12.0	9.4	0.0
11	39.6	25.6	62	33	103	11.7	9.7	0.0
12	40.0	26.1	64	35	114	11.8	9.6	0.0
13	40.5	26.3	63	34	104	11.6	9.6	0.0
14	40.2	26.4	63	35	103	11.5	8.7	0.0
15	40.2	26.1	60	34	99	11.4	8.9	0.0
16	39.6	36.6	64	38	110	11.2	8.9	0.0
17	39.5	26.6	63	38	102	11.0	9.4	0.0
18	39.3	26.1	65	36	93	11.3	9.0	0.0
19	39.0	25.0	61	37	111	11.4	9.0	0.0
20	39.9	25.6	62	35	106	11.3	8.8	0.0
21	39.5	26.3	67	38	108	11.5	8.5	0.0
22	39.2	25.7	64	38	97	11.3	8.3	0.0
23	39.7	26.1	66	37	95	10.0	9.1	0.0
24	39.2	25.8	60	37	103	11.5	8.3	0.0
25	38.8	25.3	63	38	92	11.2	8.0	0.0
26	38.5	25.7	64	37	90	11.5	8.5	0.0
27	38.4	25.7	65	36	102	11.5	8.8	0.0
28	38.5	25.8	61	35	98	11.6	9.8	0.0
29	39.1	25.3	62	35	105	11.5	8.5	0.0
30	39.2	25.3	59	34	116	11.6	10.5	0.0
31	39.0	25.4	58	33	110	11.1	10.4	0.0

SEPTEMBER

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	39.0	25.6	62	36	109	10.5	9.1	0.0
2	38.6	25.0	63	38	114	10.6	9.5	0.0
3	38.7	25.1	62	35	106	10.2	8.6	0.0
4	38.7	25.2	67	36	111	10.2	9.1	0.0
5	38.2	25.2	63	37	119	10.2	9.2	0.0
6	38.0	24.8	63	37	100	9.9	8.2	0.0
7	37.5	24.7	65	40	108	9.7	8.8	0.0
8	37.3	24.7	62	38	119	10.5	8.3	0.0
9	37.2	24.6	66	39	103	9.6	8.0	0.0
10	37.3	24.7	65	38	107	10.3	8.7	0.0
11	37.3	24.1	63	40	107	10.2	8.9	0.0
12	37.4	24.2	64	38	103	10.6	8.7	0.0
13	37.8	24.1	62	35	102	9.6	9.4	0.0
14	37.8	23.7	62	40	104	10.1	8.4	0.0
15	38.1	24.0	69	36	99	9.6	8.3	0.0
16	37.7	24.4	66	38	116	10.1	8.3	0.0
17	38.3	24.0	65	35	107	10.0	8.9	0.0
18	38.5	24.6	67	35	112	10.5	9.2	0.0
19	38.1	23.9	68	36	95	10.2	8.8	0.0
20	38.2	23.6	64	34	98	9.4	9.6	0.0
21	37.5	23.5	61	34	94	10.3	8.6	0.0
22	37.4	23.1	64	33	89	9.7	8.0	0.0
23	37.6	23.2	60	33	92	9.6	7.9	0.0
24	36.8	24.1	61	36	88	9.8	7.9	0.0
25	36.5	24.1	62	36	90	9.7	7.8	0.0
26	36.2	23.0	66	35	92	9.2	7.8	0.0
27	36.5	23.1	62	34	94	9.4	7.5	0.0
28	35.8	22.1	65	36	84	10.0	7.7	0.0
29	36.6	22.3	61	35	89	9.5	6.7	0.0
30	36.7	23.4	64	33	94	9.3	7.6	0.0

OCTOBER

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	35.6	23.4	61	38	80	8.5	7.2	0.0
2	34.9	23.9	59	36	78	8.4	7.4	0.0
3	35.9	22.1	57	33	93	8.7	6.7	0.0
4	35.8	22.7	57	35	92	8.2	7.0	0.0
5	35.7	22.7	58	33	87	8.9	7.2	0.0
6	35.1	22.0	56	32	66	9.2	6.9	0.0
7	34.7	21.5	53	32	77	9.4	7.8	0.0
8	34.5	21.2	57	36	79	9.0	7.8	0.0
9	34.5	21.6	58	35	76	9.2	7.1	0.0
10	34.3	20.8	60	37	72	9.5	6.3	0.0
11	34.0	20.6	59	33	77	9.0	5.9	0.0
12	33.5	20.9	55	38	77	8.1	6.8	0.0
13	33.7	21.2	55	37	72	9.1	5.8	0.0
14	33.4	19.8	60	36	70	9.0	6.4	0.0
15	34.0	20.6	59	34	80	8.6	6.5	0.0
16	34.7	21.5	58	36	67	8.4	6.6	0.0
17	33.9	22.7	59	42	67	8.0	6.1	0.0
18	32.9	22.1	62	42	71	8.1	4.9	0.0
19	32.2	21.1	63	39	74	8.4	5.3	0.0
20	32.4	20.8	65	38	81	8.5	6.0	0.0
21	32.8	21.0	60	38	81	9.2	5.5	0.0
22	32.5	20.6	62	38	70	8.7	5.3	0.0
23	33.2	20.0	57	36	67	8.6	5.3	0.0
24	32.1	20.2	55	38	62	8.6	5.9	0.0
25	32.3	19.9	59	39	65	8.8	6.3	0.0
26	30.9	19.8	60	40	61	8.9	5.0	0.0
27	30.5	18.5	62	37	52	8.8	5.0	0.0
28	30.3	17.6	65	38	61	8.4	4.4	0.0
29	29.9	17.9	61	37	66	8.7	4.5	0.0
30	31.5	18.8	56	39	60	7.9	4.5	0.0
31	31.9	18.7	60	33	61	9.0	5.0	0.0

NOVEMBER

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	31.5	18.8	57	33	83	7.3	5.2	0.0
2	30.5	18.4	52	38	74	6.2	4.2	0.0
3	30.0	17.7	55	39	94	6.5	4.1	0.0
4	29.4	18.1	58	37	75	7.3	4.1	0.0
5	29.8	18.6	59	38	48	7.3	3.9	0.0
6	29.1	17.7	60	41	70	7.0	3.5	0.0
7	27.9	17.4	66	45	62	6.6	3.1	0.0
8	27.5	16.2	61	39	80	7.8	3.4	0.0
9	26.5	16.1	62	41	111	6.5	3.8	0.0
10	25.9	16.3	65	43	80	7.2	3.4	0.0
11	24.3	15.2	68	52	66	6.4	2.9	0.0
12	25.6	15.0	69	42	46	8.2	3.3	0.0
13	25.1	14.1	62	43	61	8.4	3.3	0.0
14	24.4	13.0	67	40	56	7.6	3.3	0.0
15	25.5	13.3	68	44	59	7.6	3.3	0.0
16	25.7	14.3	55	38	40	7.9	3.3	0.0
17	26.1	14.0	61	46	50	7.1	3.1	0.0
18	25.7	14.4	68	45	44	7.8	2.5	0.0
19	25.7	15.1	70	45	56	8.0	3.2	0.0
20	26.2	15.1	65	43	50	7.6	3.1	0.0
21	26.3	16.0	61	38	74	7.9	4.0	0.0
22	25.6	14.6	64	37	63	8.7	3.8	0.0
23	25.6	14.5	61	43	71	7.7	3.4	0.0
24	24.7	13.4	69	43	51	6.8	3.0	4.0
25	24.5	13.0	65	41	42	6.8	2.7	0.0
26	24.2	13.5	62	42	35	6.8	2.4	0.0
27	23.5	12.7	74	48	34	7.3	2.5	0.0
28	23.2	12.8	65	48	43	6.2	2.9	0.0
29	23.1	13.0	72	49	52	5.4	2.6	0.0
30	22.2	13.4	65	48	53	5.8	2.4	0.0

DECEMBER

Date	T_{max} (°C)	T_{min} (°C)	RH_{max} (°C)	RH_{min} (°C)	U_2 (km/day)	n (hour)	E_{pan} (mm)	Rainfall (mm)
1	21.8	12.2	68	50	55	5.5	2.6	0.0
2	21.5	11.5	69	52	72	4.8	2.8	0.0
3	20.3	11.9	69	52	56	5.4	2.6	0.0
4	19.9	11.6	73	52	48	5.5	2.2	5.0
5	20.2	10.6	72	50	45	5.0	1.9	0.0
6	20.4	9.8	75	48	37	6.0	1.8	0.0
7	21.6	10.5	74	49	55	7.7	2.7	0.0
8	22.3	11.5	69	45	63	7.1	2.9	0.0
9	22.2	12.4	66	46	63	6.7	2.7	0.0
10	22.1	12.3	70	46	49	6.3	2.3	7.0
11	22.7	11.9	68	42	58	7.7	2.4	7.5
12	21.4	12.1	69	47	50	5.5	2.2	3.0
13	20.1	12.0	76	58	57	3.6	1.3	0.0
14	20.0	11.9	80	59	68	6.0	2.2	0.0
15	19.9	10.8	78	54	49	5.8	1.4	0.0
16	19.6	10.3	78	54	42	5.2	1.9	2.0
17	19.6	10.5	78	52	36	4.9	1.8	0.0
18	19.6	10.2	74	52	61	5.9	2.0	0.0
19	18.1	10.2	82	58	75	4.6	2.0	0.0
20	19.1	10.6	78	57	67	4.8	1.8	0.0
21	20.2	10.7	77	53	84	7.0	2.3	0.0
22	19.7	11.4	75	54	73	5.7	2.6	0.0
23	19.4	10.8	76	51	55	5.7	2.2	0.0
24	18.7	10.8	77	61	66	4.4	2.3	0.0
25	18.2	10.3	74	53	64	4.5	1.5	0.0
26	18.9	9.6	81	56	105	5.2	2.1	0.0
27	18.1	10.0	70	52	78	5.9	2.1	0.0
28	18.1	9.6	71	50	47	5.1	2.1	0.0
29	19.2	9.6	74	47	49	6.0	2.0	0.0
30	18.5	9.2	81	52	46	7.5	1.8	0.0
31	18.8	9.1	76	53	35	5.8	1.7	0.0

APPENDIX 2

FIELD EVALUAITON DATA

MICROIRRIGATION SYSTEM DATA COLLECTION

Initial evaluation.

Subunit No. 1 **Crop: Clementine**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	530	95.4	195	35.1	310	55.8	420	75.6
	B	430	77.4	240	43.2	380	68.4	300	54.0
	Avg	480	86.4	217.5	39.2	345	62.1	360	64.8
1/3 Down	A	350	63.0	365	65.7	475	85.5	510	91.8
	B	380	68.4	385	69.3	410	73.8	340	61.2
	Avg	365	65.7	375	67.5	442.5	79.7	425	76.5
2/3 Down	A	190	34.2	255	45.9	360	64.8	310	55.8
	B	305	54.9	220	39.6	210	37.8	175	31.5
	Avg	247.5	44.6	237.5	42.8	285	51.3	242.5	43.7
Far End	A	150	27.0	200	36.0	200	36.0	245	44.1
	B	185	33.3	250	45.0	185	33.3	160	28.8
	Avg	167.5	30.2	225	40.5	192.5	34.7	202.5	36.5
EU= 55.8%					Ks = 91%			Ea = 50.7%	

Pressures

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	6.0	4.2	5.5	3.9	5.0	3.5	5.0	3.5
	B	6.0	4.2	5.0	3.5	5.0	3.5	5.0	3.5
Far end	A	3.0	2.1	2.0	1.4	2.0	1.4	2.5	1.8
	B	3.0	2.1	2.0	1.4	2.0	1.4	2.0	1.4

A = Lateral 1
B = lateral 2

MICROIRRIGATION SYSTEM DATA COLLECTION

Initial evaluation.

Subunit No. 2 **Crop: Clementine**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	390	70.2	345	62.1	315	56.7	260	46.8
	B	475	85.5	485	87.3	410	73.8	370	66.6
	Avg	432.5	77.9	415	74.7	362.5	65.3	315	56.7
1/3 Down	A	385	69.3	210	37.8	175	31.5	425	76.5
	B	420	75.6	355	63.9	315	56.7	225	40.5
	Avg	402.5	72.5	282.5	50.9	245	44.1	325	58.5
2/3 Down	A	270	48.6	285	51.3	375	67.5	280	50.4
	B	365	65.7	225	40.5	195	35.1	315	56.7
	Avg	317.5	57.2	255	45.9	285	51.3	297.5	53.6
Far End	A	230	41.4	235	42.3	180	32.4	260	46.8
	B	155	27.9	175	31.5	205	36.9	210	37.8
	Avg	192.5	34.7	205	36.9	192.5	34.7	235	42.3
EU= 64.7%			Ks = 91%			Ea = 58.9%			

Pressures

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	5.5	3.9	6.0	4.2	6.0	4.2	5.0	3.5
	B	5.5	3.9	5.5	3.9	6.0	4.2	5.0	3.5
Far end	A	2.5	1.8	3.0	2.1	3.0	2.1	2.5	1.8
	B	2.0	1.4	2.5	1.8	3.0	2.1	2.5	1.8

A = Lateral 1
B = lateral 2

MICROIRRIGATION SYSTEM DATA COLLECTION

Initial evaluation.

Subunit No. 3 **Crop: King**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	440	79.2	410	73.8	395	71.1	315	56.7
	B	365	65.7	225	40.5	380	68.4	355	63.9
	Avg	402.5	72.4	317.5	57.2	387.5	69.8	335	60.3
1/3 Down	A	295	53.1	430	77.4	345	62.1	425	76.5
	B	310	55.8	335	60.3	220	39.6	175	31.5
	Avg	302.5	54.5	382.5	68.9	282.5	50.9	300	54.0
2/3 Down	A	235	42.3	275	49.5	305	54.9	355	63.9
	B	185	33.3	360	64.8	215	38.7	240	43.2
	Avg	210	37.8	317.5	57.2	260	46.8	297.5	53.6
Far End	A	215	38.7	205	36.9	280	50.4	195	35.1
	B	185	33.3	285	51.3	215	38.7	235	42.3
	Avg	200	36.0	245	44.1	247.5	44.6	215	38.7

EU= 68.1%	Ks = 91%	Ea = 62%

Pressures.

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	6.5	4.6	6.5	4.6	5.5	3.9	5.5	3.9
	B	6.5	4.6	7.0	4.9	6.0	4.2	5.0	3.5
Far end	A	3.5	2.5	3.0	2.1	2.5	1.8	2.5	1.8
	B	3.5	2.5	3.0	2.1	3.0	2.1	2.5	1.8

A = Lateral 1
B = lateral 2

MICROIRRIGATION SYSTEM DATA COLLECTION

Initial evaluation.

Subunit No. 4 **Crop: King**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	485	87.3	405	72.9	395	71.1	375	67.5
	B	415	74.7	345	62.1	380	68.4	325	58.5
	Avg	450	81.0	375	67.5	387.5	69.8	350	63.0
1/3 Down	A	315	56.7	270	48.6	455	81.9	305	54.9
	B	365	65.7	385	69.3	335	60.3	215	38.7
	Avg	340	61.2	327.5	59.0	395	71.1	260	46.8
2/3 Down	A	235	42.3	325	58.5	280	50.4	345	62.1
	B	175	31.5	250	45.0	205	36.9	295	53.1
	Avg	205	36.9	287.5	51.8	242.5	43.7	320	57.6
Far End	A	225	40.5	185	33.3	220	39.6	240	43.2
	B	195	35.1	245	44.1	155	27.9	215	38.7
	Avg	210	37.8	215	38.7	187.5	33.7	227.5	41.0

EU= 62.6%	Ks = 91%	Ea = 57%

Pressures

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	6.5	4.6	6.0	4.2	5.5	3.9	5.5	3.9
	B	6.5	4.6	6.0	4.2	5.5	3.9	5.0	3.5
Far end	A	3.0	2.1	2.5	1.8	2.0	1.4	2.0	1.4
	B	2.5	1.8	2.5	1.8	2.5	1.8	2.0	1.4

A = Lateral 1
B = lateral 2

MICROIRRIGATION SYSTEM DATA COLLECTION

Initial evaluation.

Subunit No. 5 **Crop: Shamouti**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	360	64.8	315	56.7	245	44.1	355	63.9
	B	285	51.3	325	58.5	310	55.8	165	29.7
	Avg	322.5	58.1	320	57.6	277.5	50.0	260	46.8
1/3 Down	A	340	61.2	270	48.6	265	47.7	285	51.3
	B	265	47.7	185	33.3	335	60.3	225	40.5
	Avg	302.5	54.5	227.5	41.0	300	54.0	255	45.9
2/3 Down	A	240	43.2	205	36.9	195	35.1	215	38.7
	B	210	37.8	295	53.1	180	32.4	225	40.5
	Avg	225	40.5	250	45.0	187.5	33.8	220	39.6
Far End	A	185	33.3	170	30.6	235	42.3	205	36.9
	B	210	37.8	195	35.1	190	34.2	215	38.7
	Avg	197.5	35.6	182.5	32.9	212.5	38.3	210	37.8
EU= 73.9%				Ks = 91%			Ea = 67.2%		

Pressures

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	4.0	2.8	4.0	2.8	4.5	3.2	4.5	3.2
	B	4.5	3.2	4.0	2.8	4.5	3.2	4.5	3.2
Far end	A	1.5	1.1	1.5	1.1	2.0	1.4	2.0	1.4
	B	2.0	1.4	1.5	1.1	2.0	1.4	2.0	1.4

A = Lateral 1
B = lateral 2

MICROIRRIGATION SYSTEM DATA COLLECTION

Evaluation under adjustment condition.

Subunit No. 1 **Crop: Clementine**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	170	35.1	200	36.0	175	31.5	160	28.8
	B	195	30.6	150	27.0	160	28.8	170	30.6
	Avg	182.5	32.9	175	31.5	167.5	30.2	165	29.7
1/3 Down	A	160	28.8	195	35.1	180	32.4	155	27.9
	B	220	39.6	165	29.7	170	30.6	170	30.6
	Avg	190	34.2	180	32.4	175	31.5	162.5	29.3
2/3 Down	A	180	32.4	160	28.8	180	32.4	175	31.5
	B	175	31.5	185	33.3	150	27.0	160	28.8
	Avg	177.5	32.0	172.5	31.1	165	29.7	167.5	30.2
Far End	A	170	30.6	185	33.3	160	28.8	190	34.2
	B	175	31.5	160	28.8	180	32.4	170	30.6
	Avg	172.5	31.1	172.5	31.1	170	30.6	180	32.4
EU= 93.8%				Ks = 91%			Ea = 85%		

Pressures

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	11.5	8.1	11.0	7.7	10.0	7.0	10.0	7.0
	B	11.0	7.7	11.0	7.7	10.5	7.4	10.0	7.0
Far end	A	10.0	7.0	9.0	6.3	8.5	6.0	8.5	6.0
	B	9.5	6.7	8.5	6.0	8.5	6.0	8.5	6.0

A = Lateral 1
B = lateral 2

MICROIRRIGATION SYSTEM DATA COLLECTION

Evaluation under adjustment condition.

Subunit No. 2 **Crop: Clementine**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	210	37.8	190	34.2	165	29.7	155	27.9
	B	160	28.8	150	27.0	185	33.3	165	29.7
	Avg	185	33.3	170	30.6	175	31.5	160	28.8
1/3 Down	A	180	32.4	160	28.8	145	26.1	165	29.7
	B	170	30.6	165	29.7	170	30.6	175	31.5
	Avg	175	31.5	162.5	29.3	157.5	28.4	170	30.6
2/3 Down	A	155	27.9	160	28.8	175	31.5	160	28.8
	B	215	38.7	205	36.9	155	27.9	175	31.5
	Avg	185	33.3	182.5	32.9	165	29.7	167.5	30.2
Far End	A	170	30.6	175	31.5	175	32.4	180	32.4
	B	195	35.1	160	28.8	180	31.5	170	30.6
	Avg	182.5	32.9	167.5	30.2	177.5	32.0	175	31.5
EU= 91.5%				Ks = 91%			Ea = 83%		

Pressures

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	9.5	6.7	9.5	6.7	9.0	6.3	8.5	6.0
	B	9.5	6.7	9.0	6.3	9.0	6.3	8.5	6.0
Far end	A	8.0	5.6	8.0	5.6	7.5	5.3	7.0	4.9
	B	8.0	5.6	8.0	5.6	7.0	4.9	7.0	4.9

A = Lateral 1
B = lateral 2

MICROIRRIGATION SYSTEM DATA COLLECTION

Evaluation under adjustment condition.

Subunit No. 3 **Crop: King**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	180	32.4	165	29.7	185	33.3	175	31.5
	B	185	33.3	150	27.0	160	28.8	180	32.4
	Avg	182.5	32.9	157.5	28.4	172.5	31.1	177.5	32.0
1/3 Down	A	185	33.3	210	37.8	165	29.7	185	33.3
	B	175	31.5	170	30.6	190	34.2	175	31.5
	Avg	180	32.4	190	34.2	177.5	32.0	180	32.4
2/3 Down	A	180	32.4	185	33.3	175	31.5	180	32.4
	B	185	33.3	165	29.7	140	25.2	150	27.0
	Avg	182.5	32.9	175	31.5	157.5	28.4	165	29.7
Far End	A	165	29.7	205	36.9	185	33.3	165	29.7
	B	170	30.6	160	28.8	180	32.4	170	30.6
	Avg	167.5	30.2	182.5	32.9	182.5	32.9	167.5	30.2
EU= 90.2%				Ks = 91%			Ea = 82%		

Pressures

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	11.5	8.1	11.0	7.7	10.5	7.4	10.0	7.0
	B	11.5	8.1	10.5	7.4	10.5	7.4	10.0	7.0
Far end	A	9.0	6.3	8.5	6.0	8.0	5.6	8.0	5.6
	B	9.0	6.3	8.5	6.0	8.0	5.6	8.5	6.0

A = Lateral 1
B = lateral 2

MICROIRRIGATION SYSTEM DATA COLLECTION

Evaluation under adjustment condition.

Subunit No. 4 **Crop: King**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	175	31.5	165	29.7	180	32.4	190	34.2
	B	195	35.1	175	31.5	160	28.8	180	32.4
	Avg	185	33.3	170	30.6	170	30.6	185	33.3
1/3 Down	A	170	30.6	185	33.3	195	34.2	160	28.8
	B	200	36.0	140	25.2	180	32.4	170	30.6
	Avg	185	33.3	162.5	29.3	187.5	33.8	165	29.7
2/3 Down	A	180	32.4	155	27.9	180	32.4	160	28.8
	B	175	31.5	165	29.7	175	31.5	190	34.2
	Avg	177.5	32.0	160	28.8	177.5	32.0	175	31.5
Far End	A	175	31.5	150	27.0	190	34.2	155	27.9
	B	185	33.3	160	28.8	175	31.5	185	33.3
	Avg	180	32.4	155	27.9	182.5	32.9	170	30.6
EU= 89%			Ks = 91%				Ea = 81%		

Pressures

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	9.0	6.3	9.0	6.3	8.5	6.0	7.0	4.9
	B	9.0	6.3	8.5	6.0	8.0	5.6	7.0	4.9
Far end	A	7.5	5.3	7.5	5.3	6.5	4.6	6.0	4.2
	B	7.5	5.3	7.0	4.9	6.0	4.2	6.0	4.2

A = Lateral 1
B = lateral 2

MICROIRRIGATION SYSTEM DATA COLLECTION

Evaluation under adjustment condition.

Subunit No. 5 **Crop: Shamouti**

Emitter Discharge

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph	ml/20 sec	lph
Inlet End	A	210	37.8	150	27.0	195	35.1	165	29.7
	B	140	25.2	175	31.5	185	33.3	140	25.2
	Avg	175	31.5	162.5	29.3	190	34.2	152.5	27.5
1/3 Down	A	155	27.9	160	28.8	145	26.1	195	35.1
	B	180	32.4	200	36.0	190	34.2	175	31.5
	Avg	167.5	30.2	180	32.4	167.5	30.2	185	33.3
2/3 Down	A	220	39.6	175	31.5	155	27.9	175	31.5
	B	170	30.6	185	33.3	185	33.3	160	28.8
	Avg	195	35.1	180	32.4	170	30.6	167.5	30.2
Far End	A	175	31.5	170	30.6	170	30.6	150	27.0
	B	190	34.2	180	32.4	195	35.1	190	34.2
	Avg	182.5	32.9	175	31.5	182.5	32.9	170	30.6
EU= 87%			Ks = 0.91%				Ea = 79%		

Pressures

Location on Lateral		Lateral Location on Manifold							
		Inlet End		1/3 Down		2/3 Down		Far End	
		psi	M	psi	M	psi	M	psi	M
Inlet	A	6.5	4.6	6.0	4.2	5.0	3.5	4.0	2.8
	B	6.5	4.6	5.5	3.9	5.0	3.5	4.0	2.8
Far end	A	5.0	3.5	4.5	3.2	3.5	2.5	3.0	2.1
	B	5.0	3.5	4.5	3.2	3.5	2.5	3.5	2.5

A = Lateral 1
B = lateral 2

$T_4R_1V_1$

T_4: Farmer method Plot

R_1: First replicate

V_1: Clementine

Lateral 1			Lateral 2		
Sprayer	Discharge (ml/20 sec)	Discharge (LPH)	Sprayer	Discharge (ml/20 sec)	Discharge (LPH)
1	510	91.8	1	480	86.4
2	510	91.8	2	460	82.8
3	360	64.8	3	475	85.5
4	370	66.6	4	385	69.3
5	420	75.6	5	360	64.8
6	275	49.5	6	280	50.4
7	250	45.0	7	260	46.8

Sprayers are numbered starting from the inlet.

Pressure	Lateral 1		Lateral 2	
	psi	M	psi	M
Inlet	6.5	4.6	7.0	4.9
Far end	4.0	2.8	4.0	2.8

$T_4R_2V_1$

T_4: Farmer method Plot

R_2: Second replicate

V_1: Clementine

Lateral 1			Lateral 2		
Sprayer	Discharge (ml/20 sec)	Discharge (LPH)	Sprayer	Discharge (ml/20 sec)	Discharge (LPH)
1	550	99	1	520	93.6
2	535	96.3	2	510	91.8
3	460	82.8	3	480	86.4
4	410	73.8	4	260	46.8
5	345	62.1	5	385	69.3
6	275	49.5	6	230	41.4
7	195	35.1	7	270	48.6

Sprayers are numbered starting from the inlet.

Pressure	Lateral 1		Lateral 2	
	psi	M	psi	M
Inlet	6.5	4.6	6.0	4.2
Far end	3.5	2.5	3.5	2.5

$T_4R_3V_1$

T_4: Farmer method Plot

R_3: Third replicate

V_1: Clementine

Lateral 1			Lateral 2		
Sprayer	Discharge (ml/20 sec)	Discharge (LPH)	Sprayer	Discharge (ml/20 sec)	Discharge (LPH)
1	445	80.1	1	420	75.6
2	465	83.7	2	400	72.0
3	360	64.8	3	355	63.9
4	335	60.3	4	270	48.6
5	410	73.8	5	335	60.3
6	290	52.2	6	310	55.8
7	225	40.5	7	230	41.4

Sprayers are numbered starting from the inlet.

Pressure	Lateral 1		Lateral 2	
	psi	M	psi	M
Inlet	5.5	3.9	5.5	3.9
Far end	3.0	2.1	3.5	2.5

$T_4R_1V_2$

T_4: Farmer method Plot

R_1: First replicate

V_2: King

Lateral 1			Lateral 2		
Sprayer	Discharge (ml/20 sec)	Discharge (LPH)	Sprayer	Discharge (ml/20 sec)	Discharge (LPH)
1	525	94.5	1	490	88.2
2	465	83.7	2	410	73.8
3	440	79.2	3	375	67.5
4	380	68.4	4	410	73.8
5	345	62.1	5	350	63.0
6	310	55.8	6	300	54.0
7	260	46.8	7	285	51.3

Sprayers are numbered starting from the inlet.

Pressure	Lateral 1		Lateral 2	
	psi	M	psi	M
Inlet	6.5	4.6	7.5	5.3
Far end	4.0	2.8	4.5	3.2

$T_4R_2V_2$

T_4: Farmer method Plot

R_2: Second replicate

V_2: King

Lateral 1			Lateral 2		
Sprayer	Discharge (ml/20 sec)	Discharge (LPH)	Sprayer	Discharge (ml/20 sec)	Discharge (LPH)
1	485	87.3	1	360	64.8
2	370	66.6	2	410	73.8
3	395	71.1	3	455	81.9
4	430	77.4	4	375	67.5
5	360	64.8	5	380	68.4
6	315	56.7	6	325	58.5
7	290	52.2	7	340	61.2

Sprayers are numbered starting from the inlet.

Pressure	Lateral 1		Lateral 2	
	psi	M	psi	M
Inlet	6.5	4.6	6.0	4.2
Far end	4.0	2.8	3.0	2.1

$T_4R_3V_2$

T_4: Farmer method Plot.

R_3: Third replicate.

V_2: King.

Lateral 1			Lateral 2		
Sprayer	Discharge (ml/20 sec)	Discharge (LPH)	Sprayer	Discharge (ml/20 sec)	Discharge (LPH)
1	245	44.1	1	350	63.0
2	395	71.1	2	485	87.3
3	355	63.9	3	450	81.0
4	375	67.5	4	380	68.4
5	350	63.0	5	395	71.1
6	315	56.7	6	295	53.1
7	280	50.4	7	320	57.6

Sprayers are numbered starting from the inlet.

Pressure	Lateral 1		Lateral 2	
	psi	M	psi	M
Inlet	7.0	4.9	6.5	4.6
Far end	4.0	2.8	3.5	2.5

$T_4R_1V_3$

T_4: Farmer method Plot

R_1: First replicate

V_3: Shamouti

Lateral 1			Lateral 2		
Sprayer	Discharge (ml/20 sec)	Discharge (LPH)	Sprayer	Discharge (ml/20 sec)	Discharge (LPH)
1	380	50.4	1	335	60.3
2	355	63.9	2	275	49.5
3	285	51.3	3	305	54.9
4	250	45.0	4	270	48.6
5	265	47.7	5	365	65.7
6	235	42.3	6	230	41.4
7	215	38.7	7	190	34.2

Sprayers are numbered starting from the inlet.

Pressure	Lateral 1		Lateral 2	
	psi	M	psi	M
Inlet	5.5	3.9	5.0	3.5
Far end	3.0	2.1	2.0	1.4

$T_4R_2V_3$

T_4: Farmer method Plot

R_2: Second replicate

V_3: Shamouti

Lateral 1			Lateral 2		
Sprayer	Discharge (ml/20 sec)	Discharge (LPH)	Sprayer	Discharge (ml/20 sec)	Discharge (LPH)
1	345	62.1	1	320	57.6
2	215	38.7	2	230	41.4
3	330	59.4	3	280	50.4
4	185	33.3	4	285	51.3
5	255	45.9	5	185	33.3
6	195	35.1	6	210	37.8
7	170	30.6	7	190	34.2

Sprayers are numbered starting from the inlet.

Pressure	Lateral 1		Lateral 2	
	psi	M	psi	M
Inlet	5.5	3.7	5.5	3.7
Far end	2.0	1.4	2.0	1.4

$T_4R_3V_3$

T_4: Farmer method Plot

R_3: Third replicate

V_3: Shamouti

Lateral 1			Lateral 2		
Sprayer	Discharge (ml/20 sec)	Discharge (LPH)	Sprayer	Discharge (ml/20 sec)	Discharge (LPH)
1	315	56.7	1	340	61.2
2	285	51.3	2	225	40.5
3	230	41.4	3	205	36.9
4	170	30.6	4	180	32.4
5	190	34.2	5	215	38.7
6	195	35.1	6	180	32.4
7	165	29.7	7	175	31.5

Sprayers are numbered starting from the inlet.

Pressure	Lateral 1		Lateral 2	
	psi	M	psi	M
Inlet	5.0	3.5	5.5	3.9
Far end	1.5	1.1	2.0	1.4

ملخص

تأثير جدولة الري على إنتاج الحمضيات تحت ظروف الري بالتنقيط في وادي الاردن

اعداد

محمد الأزهري المهدي صالح

المشرف

دكتور محمد رشيد شطناوي

اجريت هذه الدراسة في الموسم 1995 في الوحدة الزراعية رقم 226 حوض رقم 25 الواقعة في وادي الاردن الأوسط لإختبار امكانية توفير كميات من مياه الري باستخدام قيم البخر-نتح المحسوبة في جدولة الري

2واشتملت هذه الدراسة على اربعة معاملات مختلفة لري ثلاثة محاصيل من الحمضيات.

هذه المحاصيل هي:

1. كلمنتينا: Blanco *Citrus reticulata*.
2. كنج : Lour *Citrus nobitis*.
3. شموطي: (L.) Osbeck *Citrus sinensis*.

ومعاملات الري المستخدمة كانت كالتالي:

1. طريقة بنمان- مونتيث: كمية المياه اضيفت بناء على قيم البخر- نتح المحسوبة من المعلومات المناخية باستخدام معادلة بنمان-مونتيث.

٢. طريقة حوض التبخر: كمية المياه اضيفت بناء على قيم البخر-نتح المحسوبة باستخدام طريقة حوض التبخر.

٣. طريقة هارجريفز: كمية المياه اضيفت بناء على قيم البخر-نتح المحسوبة من المعلومات المناخية باستخدام معادلة هارجريفز.

٤. طريقة المزارع: في هذه الطريقة المياه اضيفت غالبا مرتين اسبوعيا لمدة ساعتين ونصف لكل رية وهي الطريقة المتبعة من قبل المزارع في مواسم الري السابقة.

وقد دلت نتائج التحليل الإحصائي على عدم وجود فروقات معنوية في الانتاج وذلك باستخدام الاربعة معاملات سالفة الذكر. حيث ان انتاج الكلمنتينا والكنج قد زاد بمعدل ٤٠,١٪، ١٣,١٪ على التوالي باستخدام طريقة المزارع في حيث أن انتاج الشموطي قد قل بمعدل ١٩,٦٪.

ايضا اظهرت النتائج وجود فروقات معنوية بين قيم كفاءة استخدام المياه المتحصل عليها باستخدام طريقة المزارع والتي كانت الاقل وبين قيم كفاءة استخدام المياه المتحصل عليها باستخدام كل من المعاملات الثلاثة الاخرى بالنسبة لصنف الكلمنتينا، أما بالنسبة لصنف الكنج فان النتائج أظهرت وجود فروقات معنوية بين المعاملة الاولى (طريقة بنمان- مونتيث) والمعاملة الرابعة (طريقة المزارع) في حين اظهرت النتائج عدم وجود فروقات معنوية بين كل من المعاملة الاولى والثانية والثالثة وايضا بين المعاملة الثانية والثالثة والرابعة.

بالنسبة لصنف الشموطي فلم تظهر النتائج أية فروقات معنوية في قيم كفاءة استخدام المياه بين كل المعاملات المستخدمة.

دلت النتائج ايضا على وجود فروقات معنوية بين كمية المياه الكلية المضافة لصنف الكلمنتينا والشموطي باستخدام طريقة المزارع والتي كانت الأكبر وبين كل من المعاملات الثلاثة الاخرى وعدم وجود فروقات معنوية بين المعاملة الاولى (بنمان-مونتيث) والثانية (حوض التبخر) والثالثة (هارجريفز).

اما بالنسبة لصنف الكنج فان النتائج اظهرت وجود فروقات معنوية بين كل المعاملات المستخدمة واكبر كمية مياه اضيفت كانت باستخدام طريقة المزارع.

كل النتائج السابقة دليل على ان المزارع يضيف كميات كبيرة من مياه الري اكبر من حاجة النبات اليها مما يزيد من فقدان المياه عن طريق التسرب العميق تحت منطقة الجذور وكذلك عن طريق التبخر من سطح التربة.