The Journal of Animal & Plant Sciences, 25(4): 2015, Page: 1008-1015
ISSN: 1018-7081

WATER REQUIREMENTS AND WATER USE OF MANGO ORCHARDS IN JAZAN REGION, SAUDI ARABIA

F. S. Mohammad*, A. I. Alamoud and S. H. Mahmoud

Department of Agriculture Engineering, College of Food and Agriculture Science, King Saud University
*Corresponding author E-mail: fdeeb@ksu.edu.sa

ABSTRACT

Assessment of crop water requirement (CWR) is of vital importance in water resources management and planning in Saudi Arabia. In the present study, data of a field experiment carried out atJazan, a semi-arid region of northern region of Saudi Arabia, were used to obtain irrigation requirements and evapotranspiration (ET) of mango orchard growth during three successive seasons (2008 to 2011). The measurements were performed within a randomly selected experimental plot with 8 × 8 m spacing between rows and plants. The soil water balance method was used to obtain the mango water requirements and the Penman–Montieth method (FAO/56) was used to determine reference evapotranspiration (ET_r). The soil water content was determined by six tensiometer sets installed at 0.20 m layer intervals from the soil surface down to a 1.20 m soil depth. The experimental plot was irrigated with a drip irrigation system based on soil-moisture status. The results showed that ET was strongly influenced by soil water availability. The comparison between measured and computed ET_r revealed higher trends for measured ET_r rates, with an average of about 5.9 mm/day. As for the net mango water use, the average daily rates ranged from 0.114m^3/tree/day for drip irrigation and 0.172 m^3/tree/day for surface irrigation. The total net annual mango water use had an averaged value of 31.63 m^3/tree/season while the average annual water requirement for mango was 6527 m^3/ha/season under drip irrigation and 9790 m^3/ha/season under surface irrigation. The mango crop coefficients ranged between 0.71 and 0.77. From an economic perspective, the variations in the total net annual mango water use in the study areas influenced the average water costs and the net economic returns of mango farms. From an economic perspective, the variations in the total net annual mango water use in the study area influenced the average water costs and the net economic returns of mango farming. The water costs represented about 11% of the average variable costs of mango farming in the study area, whereas the water costs ranged from a minimum of about 678 Saudi riyals per hectare (SR ha^{-1}).

Key words: Mango water requirement, Crop Coefficient, Lysimeter, Penman–Montieth, Reference Evapotranspiration, Water costs, Net economic returns.

INTRODUCTION

The Kingdom of Saudi Arabia (KSA) has distinct and serious water deficit problem (Ouda *et al*. 2013). KSA government has decided to re-structure the agricultural sector and reconsider the governmental support for cultivation of the high water demanding crops, such as wheat (Al-Zahrani and Baig, 2011). Al Agriculture is considered the biggest consumer of water resources in the world and can account for more than 80% of the total annual water consumption in some countries with arid regions, such as the Kingdom of Saudi Arabia (KSA). In addition, agriculture can cause water degradation through the absence of proper water management. Therefore, there is an urgent need for optimum agricultural water use, with extra emphasis on water management to prevent water pollution or the deterioration of water quality.

Various studies have been conducted in the KSA to estimate the reference evapotranspiration (ET_r) and water requirements of various crops (Mustafa*et al*.1989; Al-Omran *et al*. 2004; Al-Ghobari *et al*. 2013). The Ministry of Agriculture (Al-Zeid *et al*., 1988) conducted one of the first comprehensive studies in the KSA over 13 agricultural zones in which the $ET_r$and water requirements were estimated for the most important economic crops using the Penman equation.

Mango (*Mangifera indica: Anacardiaceae*) trees are a newly introduced in Saudi Arabia, and as its popularity grows, a considerable amount of water will be required to irrigate and maintain this expansion. However, due to the KSA's limited water resources, the study of mango water requirements is essential to achieve accurate irrigation that avoids waste while conserving water.

Bithell *et al.* (2011) estimated the total water use of mango crops to be 204.4 mm (from crop factor 0.7 x a monthly pan evaporation of 292 mm), which left 198 mm for irrigation, averaged at 6.4 mm a day, after correcting for rainfall. Because 70% of the ground was covered by mature mango trees, the 198 mm of required irrigation was reduced by 30% to 138 mm and the total water requirements were 1,000,000 L = 1 ML and 100 mm/ha = 1 ML/ha for a total irrigation requirement of 1.38 ML/ha.

There are water availability restrictions in semiarid areas, where the production of tropical fruits is more intense. For this reason, the water resources in such regions must be appropriately used in irrigation management. The world's mango growing areas have increased 42.5%, yet the fruit yield has only increased 1.3%, from 7.5 to 7.6 ton/ha (Arauz, 2000; FAO, 2003; Evans, 2008).

Mango trees, considered medium-sized with comparatively high water requirements () are usually irrigated by surface or drip irrigation methods and their water consumption varies based on many factors, including climate and soil. The annual water requirement (with no rainfall) of mature mango trees is 11976 m^3/ha/year. There is some degree of stress during the flower bud development stages (May to July), and the water use of trees subjected to water stress during these stages is 9500 m^3/ha/year (. Generally, the seasonal water use of trees not subjected to water stress varies from 20 to 44 m3/ha/day from June to November, respectively (Mostert *et al*., 1996).

Water-use efficiency has been defined as the ratio of crop yield to evapotranspiration (Simsek *et al*., 2005). The water balance method has been used for calculating the evapotranspiration (ET) of fruit orchards (Azevedo *et al*., 2006). Several tropical fruit orchards have been irrigated based on empirical coefficients, but this empirical approach suggests that the amount of irrigation water may be excessive and thus could lead to the leaching of nutrients and pesticides into the groundwater (Schaffer, 1998).

An accurate estimate of mango tree water requirements in the KSA has not been established, but the Ministry of Agriculture and Water has made some rough estimations (Al-Zeid *et al*., 1988). Estimations of water use for mango trees can also be made using the tree water requirements of other areas with similar climates, such as southern California, Egypt and Iran. Irrigation scheduling based on the empirical values of crop coefficients may reflect some aspects of production costs, fruit quality and crop yield. Surplus water can produce both increasing soil salinity and groundwater table contamination, so knowledge of the changes in water levels associated with ET and water-use efficiency in mango production is essential to improve the industry's understanding of yield-limiting factors and formulate future production strategies. In this backdrop, the present study was aimed to record reference and actual mango evapotranspiration (ET_c) and estimate the irrigation water requirements of mango trees in Jazan, Saudi Arabia.

MATERIALS AND METHODS

Field experiments were conducted on mango trees in the Jazan region of northern Saudi Arabia (16°53′N 42°33′E). The soil texture in the study region was characterised as loamy, and soil properties of the site are given in Table 1. The experimental site was selected in the middle of a mango farm. The plot comprised nine mature trees of the common variety with distances of eight metres between trees and between rows of trees. The study was accomplished in five years, including preparation stages, and valid experiments were conducted during three successive years (2008-2011).

Table 1. Soil types for the study region

Depth (cm)	Texture	EC	PH	Bulk Density	Distribution of Soil Particles		
					Clay	Salt	Sand
0-10	loam	1.8	7.67	1.54	20	46	34
10-20.	loam	2.05	7.85	1.53	22	46	32
20-30	loam	3.21	7.7	1.52	24	48	28
30-40	loam	2.8	7.95	1.53	26	50	24
40-60	loam	2.3	7.89	1.41	24	50	26
60-100	loam	2.14	8.04	1.6	16	38	46

First, concrete lysimeters were constructed and used to measure ET for alfalfa. Soil water balance components were measured using continuous soil moisture sensors to estimate the actual ET of the mango trees in the study. Crop coefficients were estimated for the mango trees in the study region, based on ET_r, and the experiments on reference crops and mango trees were repeated for three consecutive years to confirm results.

The water balance method (Fares and Alva, 1999) was used for water application. In addition to tensiometers sensing soil tension, the soil's water content was measured using "Watermark" devices, whose readings were calibrated using the gravimetric method. even sensors were used in the root zone of each tree; that is, five to estimate water use and two to estimate deep percolation under the root zone (D). These data were used as input data in the water balance equation. The amount of water to be added for irrigation was based on soil properties. A drip irrigation system with high uniformity was designed to distribute water to each mango tree. The system was equipped with pressure regulators and water meters to measure the amount of water added. The pipe network comprised all of the necessary units and parts such as valves, filters, water meters and a control board, as shown in the network design layout (Fig. 1).

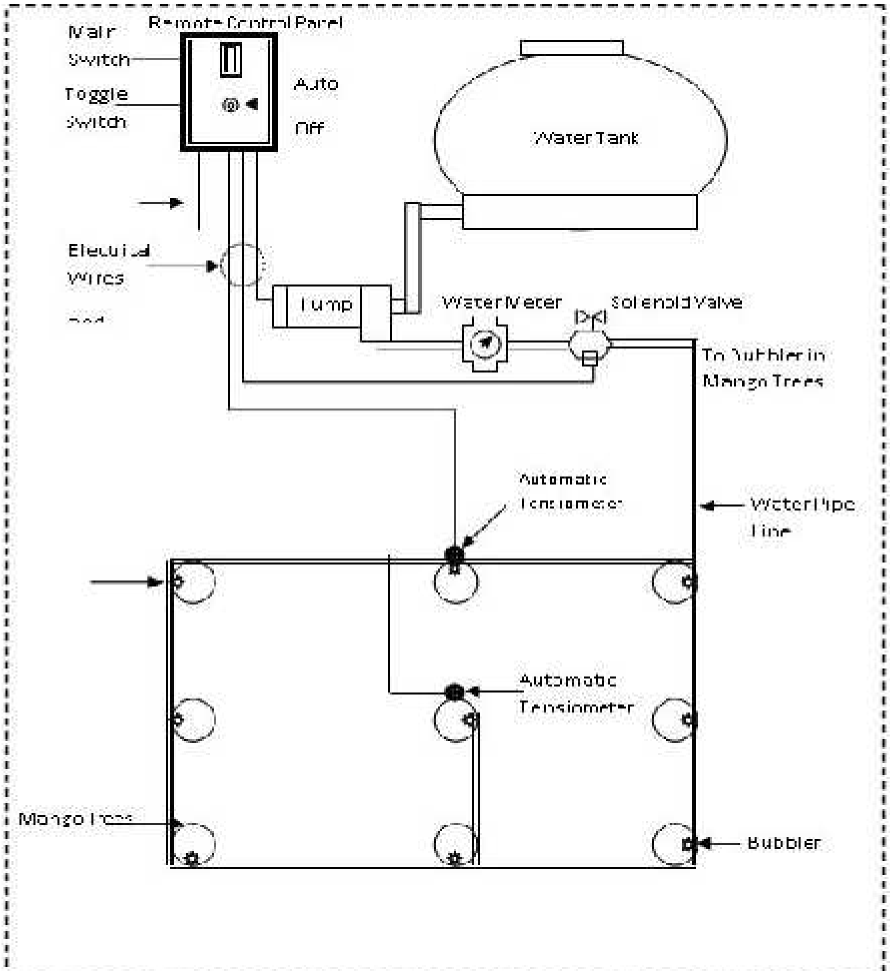

Fig. 1 Typical network design layout

The data measured by sensors were recorded electronically to calculate the changes in moisture content in the root zone (ΔW) at each depth. The (ET) estimation was calculated using the following water balance equation:

$$ET = I + P - D - (W_i - W_{i+1}) \quad \text{........ (1)}$$

where Wi is the moisture content at day (i) for all root layers, Wi +1 is the moisture content at day (i +1) for all root layers, I is the irrigation depth added each event in mm, P is the precipitation depth, if there is any, in mm and D is the drainage water depth in mm.

Fertilizer application was the same for all of the trees in accordance with the mango farm's management practices. The irrigation system was installed in January 2008 and operated through the 2011 season. The harvesting of tree yields began at the beginning of April and ended at the close of July each year.

The mango actual evapotranspiration (ET_c) was related to the ET_r using the following equation (Allen *et al*., 1998):

$$ETc = ETr \times Kc \quad \text{................ (2)}$$

where ET_r is the reference evapotranspiration, calculated using the Penman–Montieth (P–M) equation(mm/day) and K_C is the crop coefficient that incorporates the crop characteristics and averaged effects of evaporation from the soil.

The combined FAO P–M method, which was used to calculate the ET_r because it was more universally applicable than other equations (Allen*et al*., 1998) and more appropriate for the prevailing circumstances in the KSA, takes the following form:

$$ET_r = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \text{....... (3)}$$

where R_n is the net solar radiation at the surface of the crop ($MJ/m^2/day$), G is the soil heat flow intensity ($MJ/m^2/day$), T is the average daily air temperature at a height of 2 metres (C°), u_2 is the wind speed at a height of 2 metres (m/s), e_s is the saturated vapour pressure (kPa), e_a is the actual vapour pressure (kPa), $e_s - e_a$ is the saturated vapour pressure deficit (kPa), Δ is the vapour pressure at saturation and temperature gradient at air temperature (kPa/C°) and γ is the moisture constant (kPa/C°).

A computer program was developed to calculate the ET_r using the P–M equation. The total water requirements for irrigated mangos were calculated, taking into account the irrigation efficiency (70% and 90% for the surface and drip system methods, respectively) and leaching requirements at different salinity levels (0.5, 1, 2 and 3 mmho/cm) using the following equation:

$$TWR = \left(\frac{ETc}{E} \times \frac{1}{1 - LR}\right) \quad (4)$$

where TWR is the total water requirement (m^3/ha), ET_c is the net water use (m^3/ha), E is the efficiency (%) and LR is the leaching requirements, which were calculated using the following equations (Doorenbos and Pruitt, 1977):

A. For the surface irrigation method:

$$LR = \frac{EC_w}{5EC_e - EC_w} . \frac{1}{LR} \quad (5)$$

B. For the drip irrigation system:

$$LR = \frac{EC_w}{2\max . EC_e} . \frac{1}{LE} \quad (6)$$

where EC_w is the electrical conductivity of water (mmho/cm), EC_e is the electrical conductivity of the soil extract (mmho/cm), max EC_e is the maximum electrical conductivity of the soil extract tolerated by mangos (mmho/cm) and LE is the leaching efficiency (90% for sandy and loamy soils).

The computer program included an extensive database that includes weather, crop, soil and water data for the site.Significance tests, such as t- and f-tests at the 1% level were applied to estimate the levels of significant differences between the means of the measured and calculated ET_r within the study area. Pearson correlation coefficients were also applied to estimate the level of correlation between the means of the measured and calculated ETr within the study areas.

RESULTS AND DISCUSSION

The prevailing weather conditions for the study region are shown in Table 2, which indicates that the study area is characterised by high summer temperatures with low rain. However, the highest average temperature recorded was about 33.65°C in the eastern region in July. As for relative humidity, Jazan province had an average high of 74.22% in the winter months. Rainfall was generally insignificant, but relatively high quantities were recorded in the Jazan region, with less than 20 mm January through April.

Table 2. Weather conditions for the study region

Month	T	RH	WS	RS
	°C	%	m/s	Mj/M2/day
1	26.43	74.22	5.25	21.42
2	27.27	73.79	5.15	23.93
3	28.56	71.11	5.32	26.83
4	30.75	66.03	5.14	28.29
5	32.71	62.9	5.05	29.42
6	33.56	64.73	5.77	29.1
7	33.65	61.26	6.54	29.15
8	33.41	64.61	5.94	28.6
9	32.94	67.9	5.23	27.02
10	31.3	67.4	4.94	24.78
11	29.17	70.1	4.82	21.74
12	27.17	73.51	5.04	20.71

The ET_r of the study region was evaluated with a lysimeter measurement scale and a calculation scale via the P–M equation. The monthly measured ET_r of alfalfa grown in lysimeters for the study region is shown in Table 3. The daily cumulative ET_r for the study region fell within the range of 3.9 and 7.7 mm/day.

Table 3. Monthly measured ET_r of alfalfa grown in lysimeters for the study area.

Month	ET_r (mm/day)	K_C	ET_c (mm/day)
1	3.90	1.00	3.90
2	4.60	1.00	4.60
3	5.40	1.00	5.40
4	6.30	1.00	6.30
5	7.10	1.00	7.10
6	7.30	1.00	7.30
7	7.70	1.00	7.70
8	7.20	1.00	7.20
9	6.60	1.00	6.60
10	5.70	1.00	5.70
11	4.70	1.00	4.70
12	4.20	1.00	4.20

The results revealed that the average daily measured ET_r rate was 5.9 mm/day in January, whereas high summer values exceeded 10 mm/day and the values calculated by the P–M equation ranged from 2.14 to 16 mm/day. These values, measured and evaluated, were then regressed against each other (Fig. 2). As Fig. 2 shows, there is a good fit between the measured and calculated ET_r. The values calculated using the P–M equation followed similar trends as the measured values, which seemed to be consistent throughout the year. However, the calculated values slightly underestimated the ET_r –a consistent behaviour in almost all locations due to high evaporative demands. The minor underestimation of the calculated ET_r could be attributed to the fact that the method includes some empirical functions those are subject to local calibration. The minor difference between calculated and measured values indicated the need to modify the method for Saudi Arabia's hot climate. However, no such calibrations were attempted in this work.

The goodness of fit was statistically analysed and no significant differences were observed between the means of the measured and calculated ET_r within the study area using different tests of significance at the 1% level –implying the consistency of the ET_rwithin the study area. In addition, the Pearson correlation coefficients showed a strong correlation between the means of the measured and calculated ET_r within the study area (Fig. 2).

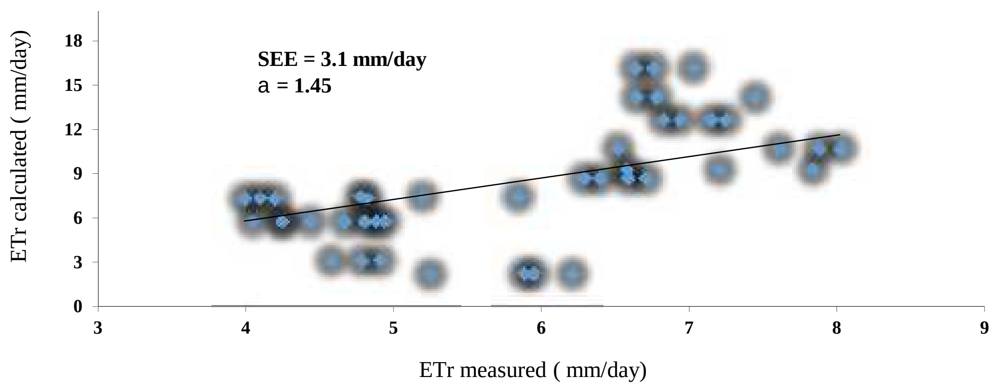

Fig 2. Pearson correlation for study region

The results of the net actual monthly mango water consumption, ET_c, measured values using the water balance method and are shown in Fig. 3, which demonstrates a normal trend influenced by weather conditions such as temperature, similar to the trends in Jensen *et al*. (1990). The annual cumulative ET_c fell within the range of 1,011 and 2,164 mm/year. The average daily net mango water use rates measured varied from 54000 to 116000 mm /day.

The comparison between the average net cumulative annual amounts consumed by mangos over the three years of study is shown in Fig. 3. It indicated some differences in mango water consumption, mainly due to variations in climatological conditions, soil and/or date variety type. Irrigation scheduling was done with the aid of tensiometers and the quantity of water applied was measured with flow meters. During the winter, the rainfall depth in Jazan varied seasonally, so the water balance technique was ideal for determining the ET_c of mango trees during the entire study period. The results showed that the total daily water requirements of the mature mango trees under optimal irrigation varied from 54000 to about 116000 mm/day.

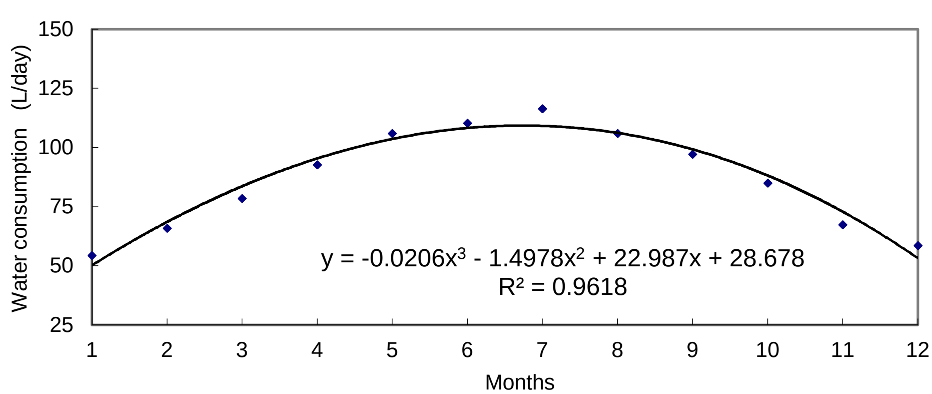

Fig. 3 Comparison of the average net cumulative annual water amounts consumed by mangos

The mango crop coefficients, K_C, were computed over the period of study using equation (2) and the average monthly K_C values are shown in Table 4. The range of K_C was between 0.71 and 0.77. The results indicated that the average crop coefficient values for each month of the year were not equal in the study region.

Table 4. Average monthly mango crop coefficients

Month	ET_r (mm/day)	K_C	ET_c (mm/day)
1	3.90	0.71	2.77
2	4.60	0.73	3.36
3	5.40	0.74	4.00
4	6.30	0.75	4.73
5	7.10	0.76	5.40
6	7.30	0.77	5.62
7	7.70	0.77	5.93
8	7.20	0.75	5.40
9	6.60	0.75	4.95
10	5.70	0.76	4.33
11	4.70	0.73	3.43
12	4.20	0.71	2.98

The results in Table 4 were also obtained from several correlation equations based on a regression analysis of the actual alfalfa and mango data for each month in the year.

According to the measured ET_c, the gross (total) mango water requirements (TWR) were calculated for the study region under the common irrigation systems (surface and drip) in the area. The TWR for mango trees was determined for four levels of irrigation water salinity and the results (Table 5) are within the range reported by Mostert *et al*. (1996) and Bithell *et al*. (2011).

To determine the TWR for mango growth under different salinity conditions, four levels of irrigation water salinity were used. The results showed that salts can be leached by applying more water than that needed by the mango trees during the growing season, as shown in Table 5. This extra water moved the salts below the root zone through deep percolation, controlling the soluble salts brought in by the irrigation water. Ultimately, over time, the salt is removed when the applied water leaches equal or excessive amounts of the added salt. The obtained results (Table 5) revealed that the increases in TWR using surface irrigation were 439.95, 1029.79 and 1293.84 m^3/ha/seasonunder water salinities of 0.5, 1, 2 and 3, respectively. The amounts of water applied by the drip irrigation system using the four levels of water salinity were 2874, 3020.72, 3363.98 and 10595.26 m^3/ha/season.

Table 5. Gross (total) mango water requirements

EC_w	ET_r	ET_c	TWR		Comparing TWR by mango		
			Surface Irr.	Drip Irr.	Surface Irr. vs EC_w	Drip Irr. VsEC_w	Surface - Drip
mmohs/cm	(mm/day)	(m^3/ha/season)	(m^3/ha/season)	(m^3/ha/season)	(m^3/ha/season)	(m^3/ha/season)	(m^3/ha/season)
0.5	0.04630	4933.84	8622.2	5748.2	0	0	+2874
1.0	5.90	4933.84	9062.15	6041.43	+439.95	+293.23	+3020.72
2.0	5.90	4933.84	10091.94	6727.96	+1029.79	+686.53	+3363.98
3.0	5.90	4933.84	11385.78	7590.52	+1293.84	+862.56	+10595.26

As Table 5 shows, the net daily mango water use ranged from 114000 mm/tree/day for drip irrigation to 172 l/tree/day for surface irrigation. The total net annual mango water use had an averaged value of 31.63 m^3/tree/season while the average annual mango water requirement was 6527 m^3/ha/season under drip irrigation and 9790 m^3/ha/season under surface irrigation. These values were within the range reported by Mostert *et al*. (1996) and Bithell *et al*. (2011).

From an economic perspective, the variations in the total net annual mango water use in the study area influenced the average water costs and the net economic returns of mango farming. The water costs represented about 11% of the average variable costs of mango farming in the study area, whereas the water costs ranged from a minimum of about 678 Saudi riyals per hectare (SR ha^{-1}). The average productivity of mango trees in the Jazan region is 5.60 (t/ha) and the cost of production is 10972.63 (SR/ha) while the average price is 4.75 (SR/kg).

Conclusions: The aim of this study was to measure the reference and actual ET and estimate the irrigation water requirements of strategic crops in the KSA. Thus, extensive field experiments were conducted on crops in lysimeters and on trees using the soil water balance method. The study was accomplished in five years. Lysimeters were installed during the first two years, during which alfalfa was grown in accordance with the research plan after soil preparation, irrigation system installations and soil and water analyses.

Lysimeters were used to measure actual ET for alfalfa as a first step in calculating the ET and crop coefficients for mango trees. The soil's water balance was measured using continuous soil moisture sensors to estimate ET for mango trees. The experiments with alfalfa and mango trees were repeated for three consecutive years to confirm the results. The highest measured monthly values were found to occur in July (January). The annual cumulative ET_r for the study region fell within the range of 1423 and 2810 mm/year. The values calculated using the P–M equation followed similar trends as the measured values, which were consistent throughout the year. However, the calculated values slightly underestimated the ET_r.

The net actual monthly mango water consumption, ET_c, for the study region demonstrated a normal trend influenced by weather conditions. The annual cumulative ET_c for the study region fell within the range of 1011 and 2164 mm/year. The average daily net mango water use rates varied from 54000 to 116000 mm/day.

The comparison of the average net cumulative annual water amounts consumed by mangos over the three years of study for the region revealed some differences, mainly due to variations in climatological conditions, soil and/or date variety types. The close correlation between the actual and predicted values demonstrated the suitability of using a modified Penman equation in the arid conditions of Saudi Arabia. Therefore, the P–M equation satisfactorily simulated the ET_r with reliable meteorological data. The variations in the water salinity for the study area influenced the water quantity and cost. The increase in water salinity led to a significant increase in the TWR under surface irrigation, and the extra water moved the salts below the root zone by deep percolation. For example,under water salinities of 0.5, 1, 2 and 3 the TWR were 439.95, 1029.79 and 1293.84 m^3/ha/season,respectively. Water costs ranged from a minimum of about 678 Saudi riyals per hectare (SR ha^{-1}). The average productivity of mango trees is 5.60 (t / ha) in the study region, with a cost of production of 10972.63 (SR/ha) and an average price of 4.75 (SR/kg).

Acknowledgment: This research is the result of a national project funded by King Abdul-Aziz City for Science and Technology (NRP-23-1) of the Kingdom of Saudi Arabia. The authors of this research are thankful for the great support, follow up and encouragement.

REFERENCES

Al-Ghobari, H. M., F, S. Mohammad, and M. S. A. El Marazky (2013). Effect of intelligent irrigation on water use efficiency of wheat crop in arid region. J. Animal Plant Sci.,23(6), 1691-1699.

Allen, R.G., L. S. Pereira, D. Raes, and M. Smith (1998). Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper No. 56. FAO - Food and Agriculture Organization of the United Nations Rome, Italy.

Al-Omran, A.M., F. S. Mohammad, H. M. Al-Ghobari, and A. A. Al-Aazba (2004). Determination of evapotranspiration of tomato and squash using lysimeters in central Saudi Arabia. Intl. Agri. Engineering J., 13 (1- 2): 27–36.

Al-Zahrani, K. H., and M. B. Baig (2011). Water in the Kingdom of Saudi Arabia: sustainable management options. J. Anim. Plant Sci., 21(3), 601-604.

Al-Zeid, A. A., E. U. Quintana, M. I. Abu Khate, M. N. Nimah, F. H. Al-Samerai and I. I. Bashour (1988). Guide for crop water requirements in the Kingdom of Saudi Arabia. Department of Agricultural Developments, Ministry of Agriculture and Water, 106 pp.

Arauz, L. F. (2000). Mango Anthracnose: Economic Impact and Current Options For Integrated Management. Plant Disease, 84(6), 600-611.

Azevedo, P.V., I. F. Sousa, B. B. Silva, and V. P. R. Silva (2006). Water-use efficiency of dwarf-green coconut (Cocoas nucifera L.) orchards in northeast Brazil. Agric. Water Manage. 84, 259–264.

Bithell, S.L. and S. Smith (2011). The method for estimating crop irrigation volumes for the Tindall limestone aquifer, Katherine, water allocation plan. Northern Territory Government, Australia. Technical Bulletin No. 337.

Doorenbos, J. and W. O. Pruitt (1977). Guidelines for predicting crop water requirements. FAO Irrigation and Drainage paper No. 24, Rome. 144 pp.

Evans, E.A. (2008). Recent Trends in World and US Mango Production Trade, and Consumption. University of Florida. Food and Resource Economics Department, Gainesville, Florida.

FAO, (2003). FAO Statistics. Retrieved on August 9, 2003, from http://www.fao.og.

Fares, A. and A. K. Alva (1999). Estimation of citrus evapotranspiration by soil water mass balance. Soil Science. 164(5): 302–310.

Jensen, M.E, Burman, R.D. and Allen, R.G. (Eds.). (1990). Evapotranspiration and irrigation water requirements. ASCE, 332 pp.

Mostert, P.G. and J. E. Hoffman (1996). Water requirements and irrigation of mature mango trees. In V International Mango Symposium 455 (331–338).

Mustafa, M.A., K. A. Akabawi, and M. F. Zoghet (1989). Estimation of reference crop evapotranspiration for the life zones of Saudi Arabia. J. Arid Environ. 17, 293–300.

Ouda, O. K., A. A. Al-Shuhail, T. Qubbaj, and R. Samara (2013). Assessing the applicability of Ground Penetrating Radar (GPR) Techniques for estimating soil water content and irrigation requirements in the Eastern Province of Saudi Arabia: A project methodology. International J. Adv. Res. Engineering and Techno. 4, 114-123.

Schaffer, B. and G. O. Gaye (1989). Effect of pruning on light interceptions, specific leaf density, leaf chlorophyll content of mango. Scientia Hort. 41, 55–61.

Simsek, M., T. Tonkaz, M. Kacira, N. Comlekcoglu and Z. Dogan (2005). The effects of different irrigation regimes on cucumber (Cucubis sativa L.) yield and yield characteristics under open field conditions. Agric. Water Manage. 73, 173–191.