Effect of Different Water Regimes on Yield and Quality of Apple under Semi-Humid Region, Libya

Ahmed M. Hassan[1]

[1] Agricultural Engineering Dept., Faculty of Agriculture, Cairo University. EGYPT

ABSTRACT

This study, which was carried out in 2011/2012, investigated the yield and quality parameters of apple fruits (double red delicious) with different irrigation systems; surface and drip irrigation and with different water levels; 100, 75 and 50% of ET_c. In order to traditional irrigation (rainfall irrigation) treatment, that presented 34.75% from ET_c. The water irrigation requirement was determined by using Penman-Monteith's equation. An increase in fruit yield and quality (fruit diameter, fruit weight, total soluble solid and sugar) has been noted with drip irrigation method if comparing with surface and rainfall irrigation. The highest fruit diameter (80.9 mm), fruit weight (216.3 g), extra and class 1 fruit ratios (36.2 and 36.5%), total soluble solid (1.551 ton/fed) and sugar (1.38 ton/fed) were observed with DET_{100} treatment. To obtain a high quantity and quality apples, DET_{100} treatment with 100% ET_c and drip irrigation system is recommended during transition from rainfall and surface irrigation to drip irrigation for similar climatic and soil conditions. The results showed that drip irrigation system increases the qualitative and quantitative of apple fruits.

Key words: surface and drip irrigation, deficit irrigation, apple yield, water use efficiency, quality parameters.

1. INTRODUCTION:

Deficit irrigation is a strategy which allows a crop to sustain some degree of water deficit in order to reduce irrigation costs and potentially increase revenues. [English, 1996], described three deficit irrigation case studies in which the reductions in irrigation costs were greater than the reductions in revenue due to reduced yields. Deficit irrigation can lead, in principle, to increased profits where water costs are high or where water supplies are limited. In these case studies, crop value was associated closely with yield, and crop grade and marketability were not germane. Under these circumstances, deficit irrigation can be a practical choice for growers. In general, deficit drip irrigation was

shown to initially increase yield as a result of induction of stress and the production of a higher number of fruits [Fallahi, et al., 2010].
Deficit irrigation may have a positive impact on environmental quality. [Dabbou, et al., 2010], studied the effect of three irrigation regimes on the fruit and quality of oil olive, the results showed that irrigation positively affected both fruit and oil quality. [Shock, et al.,1992], stated that potatoes can tolerate limited deficit irrigation before tuber set without significant reductions in external and internal tuber quality. [UNECE STANDARD, 2007;2011], stated that the quality parameters of apple fruits which take into consideration are fruit diameter, weight, fruit size classification, content of soluble solids (TSS), firmness, starch conversion, streif Index, background colour, polyphenols and anthocyanins content. Firmness is an important quality attribute especially for shipment to distant markets. [Caspari, et al., 1996], found no change in firmness of Asian pear grown under water deficit. In apple, fruit from plants grown under water deficit conditions were firmer as observed by [Kilili, et al., 1996a]. The content of total soluble content includes soluble sugars, organic acids, sorbitol, some inorganic substances and vitamins are important indicator of the maturity level [Maja, et al., 2009]. Numerous authors have reported an increase in TSS under plant deficit [Kilili, et al.,1996a; Mills, et al., 1996]. In Alagoas (Brazil), the drought period determines the sugar apple production period, so the use of irrigation is essential as a way of staggering production over the year [Endres, et al., 2007]. Maria, et al., 2006], evaluated the influence of seven different levels of irrigation applied to trees grown in a super high density orchard in the Sacramento Valley of California. The results showed that the total polyphenol levels and oxidative stability decreased as the trees received more water.
The objectives of this research were: [i] to determine apple fruit yield response to deficit irrigation by fully and partial ET_c replacement; [ii] to compare the responses of several quality parameters to deficit irrigation under surface and drip irrigation systems and; [iii] to evaluate the potential for surface and drip irrigation to improve the apple production and quality.

2. MATERIALS AND METHODS:

- **Experimental conditions:**

The study was conducted at Elbayda, Libya. Experiment was done during the 2011/2012 growing season in a commercial apple (double red delicious) orchard (spacing 5×5 m) in Raas-Eltorab (latitude 32^{o} 44$^{'}$, longitude 21^{o} 53$^{'}$). The elevation of region is 649 m high, with average temperatures ranged between 9.5 and 23.6 ^{o}C, rainfall of 549.1 mm, and relative humidity ranged between 59 to 79.3%, Table 1.

Table 1: Monthly climatic data of the experimental area

Month	Climatic parameters						
	T_{min} (^{o}C)	T_{max} (^{o}C)	T_{ave} (^{o}C)	RH (%)	Rainfall (mm)	Wind speed (m/sec)	Sunshine (h)
Jan.	6.6	12.4	9.5	79.3	120.5	1.05	6
Feb.	6.4	12.9	9.7	78.6	83.2	1.53	7
Mar.	7.5	15.4	11.5	77.7	71.7	2.3	7
Apr.	10.2	19.7	15.0	75.4	21.9	3.13	8
May	13.6	24.0	18.8	59.0	9	3.8	10
Jun.	16.6	27.2	21.9	58.9	0	4.16	12
Jul.	18.8	28.1	23.5	61.3	0	4.57	12
Aug.	19	28.1	23.6	62.3	0.7	4.38	12
Sep.	17.8	26.3	22.1	62.3	9.8	2.52	10
Oct.	15.3	23.4	19.4	62.4	40.3	2.35	8
Nov.	11.1	18.2	14.7	63.2	71.4	1.34	7
Dec.	8	14.0	11.0	64.1	120.6	0.88	6

- **Experimental design and treatments:**

One-hundred forty-four (5 years old) apple trees (Double red delicious) were divided into seven blocks of twenty four trees. Each block had three replicates of eight trees with at least one guard tree between each block. Two irrigation systems, surface (S) and drip irrigation (D), were assigned to these blocks. Each irrigation system provides the apple trees three water levels (100%, 75 %, and 50% from apple irrigation water requirements; ET_c), in order to traditional treatment (RET) which irrigated by rainfall irrigation (549.1 mm) as shown in Table (2) $RET_{34.75}$ treatment presents 34.8 % from water irrigation requirement of apple according to water irrigation requirement calculated by Penman–Monteith equation. The entirely random experimental design was based on two factors, i.e., irrigation system and water level and three replicates for each.

Table 2: Experimental design and treatments

Irrigation treatment	Irrigation system	Description	Total water applied, Mm	Net water applied, mm
SET100	Surface	100 % ET_c restoration	1580	1031
SET75	Surface	75 % ET_c restoration	1185	636
SET50	Surface	50 % ET_c restoration	790	241
DET100	Drip	100 % ET_c restoration	1580	1031
DET75	Drip	75 % ET_c restoration	1185	636
DET50	Drip	50 % ET_c restoration	790	241
RET34.75*	Rainfall	34.8 % ET_c restoration	549.1	549.1

- Traditional treatment (Total water distributed was computed by Penman–Monteith equation, [13].

Determination of crop water irrigation requirement:

[FAO 1992; 1993; 1998] has facilitated the calculation of crop water requirements and irrigation planning through a series of technical papers. The FAO Penman–Monteith equation was used to calculate the reference evapotranspiration ET_o. Crop water requirements (ET_c) over the growing season were determined from ET_o according to the following equation using crop coefficient K_c:

$$ET_c = K_c \,.\, ET_o$$

where ET_c is the crop water requirement, K_c is the crop coefficient and ET_o is the reference evapotranspiration. Since there was rainfall (549.1 mm) during the experimental period, net irrigation requirement was taken to be equal to (ET_c – Rainfall).

Yield and mean fruit weight:

Fruit yield per tree was recorded as sum of individual weight of fruit from that tree. Also the weight of apple fruit was determined using a digital balance (Model GB3002) with an accuracy of 0.01 g.

Water use efficiency:

Water use efficiency (WUE, kg/m^3) was calculated as the ratio between fresh total yield (kg/ha) and total water used (m^3/ha), [Lovelli, et al., 2007].

Moisture content of apple fruit:

Apple fruits were washed and dried then cut into thin slices. The slices placed in an oven set to about 105°C for 24 hours and weighed again. Moisture content can be calculating by the equation:

$$\text{Moisture content} = \frac{\text{Initial weight} - \text{dry weight}}{\text{Initial weight}} \times 100$$

Fibers content in apple fruit:

Apple fibers were obtained by washing, coring, chopping and separation of juice by pressing, then it was dried at 60 °C during 30 min. Each treatment was replicated three times.

Standard quality parameters measurements:

Changes in apple fruit quality during growth were assessed in the experiment at seven water regimes using 100 fruits per replicate for each treatment. Fruits were randomly sampled from outer and mid-canopy positions.

According to [UNECE STANDARD, 2007;2011], which concerning the marketing and commercial quality control of apples, the quality parameters measured in this research were fruit diameter, weight, fruit size classification, total soluble solids (TSS), firmness and sugar content. The samples were tested in faculty of science – Omar El-Mukhtar University according to [AOAC, 1990].

The firmness of a fruit is linked to the state of maturity and ripeness. The skin was removed using slicers to a 1 mm cutting depth, and flesh firmness was then measured with a dynamometer (Model WAGNER, 20 kg – Force Dial FDK 40 – Italy) equipped with a 8 mm diameter plunger tip that penetrate the flesh of apple to a depth of 11 mm. The firmness was measured in three positions; upper and down apple fruit in the x-axis (length), third position in the minor dimension (width) at right angles to the longitudinal axis (thickness), [Mohsenin, 1986]. Fruit size classification was divided into four categories according to [Kücükyumuk, et al., 2012]; Extra (>75 mm), class 1 (68–75 mm), class 2 (60–68 mm), and other (<60 mm).

3. RESULTS AND DISCUSSION:

- **Apple water irrigation requirements:**

The total amounts of irrigation water applied during 2011/2012 season for the irrigation levels treatments in this study were 1580 mm for each SET_{100} and DET_{100} treatments, 1185 mm for each SET_{75} and DET_{75}

treatments and 790 mm for each SET_{50} and DET_{50} treatments. The water requirement determined for different months by using FAO Penman-Monteith's formula based on crop growth stages and climatic data. For treatment $RET_{34.75}$, the water irrigation applied was 549.1 mm by rainfall.

- Apple tree yield and mean fruit weight:

The average values of apple tree yield and fruit weight are shown in Fig. (1) It's clear that average gross yields per tree for surface irrigation system, were 51.6, 54.7 and 59.7 kg for treatments SET_{50}, SET_{75} and SET_{100}, respectively and the corresponding mean fruit weights were 134.3, 136.2 and 149.4 g. For drip irrigation system, the gross yield per tree was 51.8, 65.0, and 67.9 kg for treatments DET_{50}, DET_{75} and DET_{100}, respectively and the corresponding mean fruit weights were 144.7, 199.7 and 216.3 g. For traditional treatment (RET34.75), the gross yield per tree was 49.3 kg and the corresponding mean fruit weight was 121.6 g, Fig. 1. The results showed that treatments DET_{75} and DET_{100} had mean fruit weight greater than other treatments.

- Effect of water regimes on water use efficiency:

The average values of apple water use efficiency (WUE) are shown in Fig. (2); it's clear that the *WUE* values were higher with drip irrigation treatments if compared with surface irrigation treatments. The maximum *WUE* (2.62 kg/m^3) treatment was DET_{50} and the minimum *WUE* (1.38 kg/m^3) treatment was SET_{50}. Treatment RET34.75 recorded

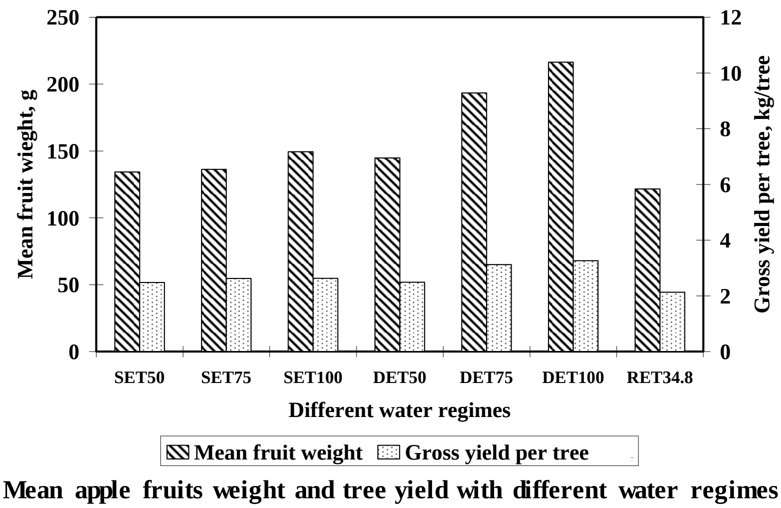

Fig. 1: Mean apple fruits weight and tree yield with different water regimes.

the maximum value (3.22 kg/m^3) than both surface and drip irrigation systems. In general *WUE* increased with water irrigation decreased on both irrigation systems used in the study.

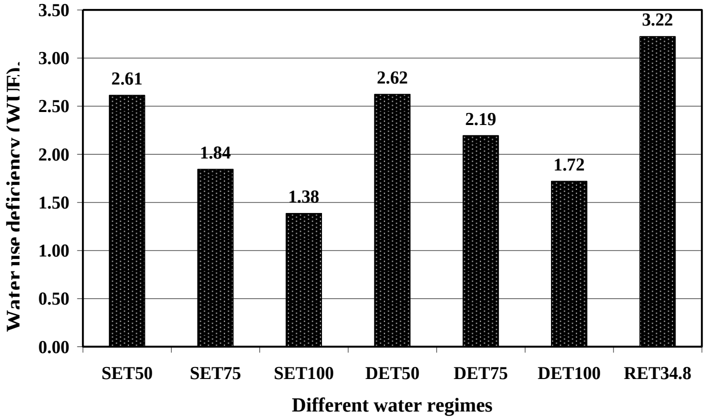

Fig. 2: Water use efficiency (WUE) under different water regimes.

- **Moisture content of apple fruit:**

As shown in Fig. 3, the total moisture content of apple fruit was decreased by increasing water irrigation applied. The maximum value of moisture content in apple fruit was 86.7% for treatment DET_{100} and the minimum value was 81.5% for treatment SET_{50}. For treatment RET34.75, moisture content was 81.4%. The total water content values in fruits were higher with drip irrigation treatments if compared with surface irrigation treatments, Fig. 3.

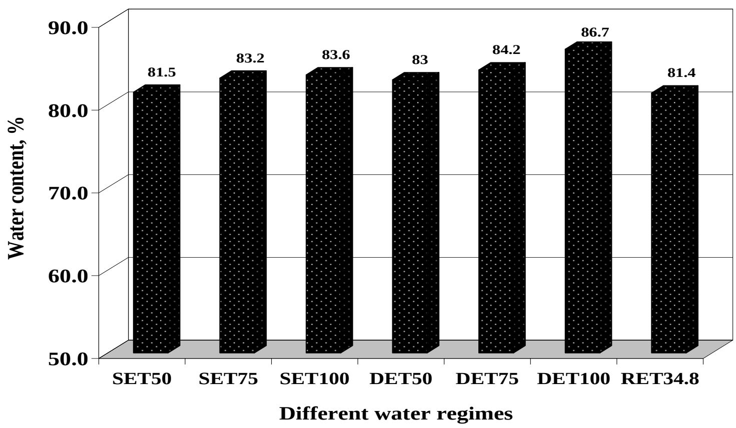

Fig. 3: Total water content of apple fruit at different water regimes.

- **Fibers content of apple fruit:**

Results of fibers content measurements are presented in Table 3 and Fig. 4. The results showed that the total fibers content were decreased by increasing water irrigation applied. Surface irrigation treatment (SET_{50}) indicated higher fibers content (5.8%) value, while drip irrigation treatment (DET_{100}) indicated lower fibers content (3.8%) value, Table 3. For traditional treatment RET34.75, fibers content was 6.2%. The total fibers content values in fruits were higher with surface irrigation treatments if compared with drip irrigation treatments, Fig. 4. According to the productivity of apple fruits per each irrigation treatment found that total fiber content differed. Thus the maximum value was 0.503 ton/fed for SET_{50}, while the minimum value was 0.358 ton/fed for SET_{100}, Fig 4.

Table 3: Effect of different water regimes on TSS, flesh firmness, sugar, phenols, fibers, moisture content, mean tree fruit weight and yield of the apple fruit.

Attributes	Water regimes						
	SET_{50}	SET_{75}	SET_{100}	DET_{50}	DET_{75}	DET_{100}	RET34.75
TSS, %	15.7	13.9	13.5	15.8	13.8	13.6	16.3
Firmness, kg/cm^2	7.86	6.26	6.18	6.93	6.11	6.10	8.05
Sugar, %	14.5	13.5	13.4	12.7	12.5	12.1	15.3
Fibers, %	5.8	5.3	3.9	4.6	4.1	3.8	6.2
Moisture content, %	81.5	83.2	83.6	83.0	84.2	86.7	81.4
Gross yield per tree, kg/tree	51.6	54.6	54.7	51.8	65.0	67.9	44.3
Yield, ton/fed.	8.67	9.17	9.19	8.70	10.92	11.41	7.44

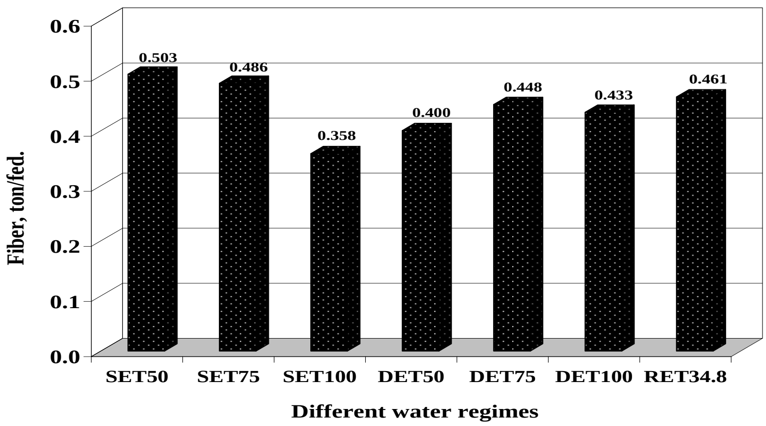

Fig. 4: Total productivity of apple fruits fiber at different water regimes.

- **Fruit quality responses to different water regimes:**

Fruit length, thickness, diameter (width), mass and volume:

The highest fruit length, thickness, width, mass and volume values were obtained from DET_{100} treatment. SET_{75} treatment showed the lowest fruit thickness, width, mass and volume values, while the fruit length value was the lowest in DET_{50} treatment. It was identified that fruit length, thickness, width, mass and volume values increased with increasing amounts of irrigation water in surface and drip irrigation treatments, Table 4. In all cases RET34.75 treatment was lowest values than other treatments whether drip or surface irrigation.

Table 4: Fruit length, diameter (width), thickness, mass and volume for different water regimes.

items	SET_{50}	SET_{75}	SET_{100}	DET_{50}	DET_{75}	DET_{100}	RET34.75
Length, mm	63.6	64.6	65.3	62.4	68.2	74.0	60.0
Diameter (width), mm	67.7	69.2	70.7	71.0	76.0	80.9	64.3
Thickness, mm	64.4	67.7	70.3	67.7	72.6	77.5	60.9
Mean fruit weight, g	134.3	136.2	149.4	144.7	193.3	216.3	121.6
Volume, cm^3	154.7	171.2	185.8	167.7	210.9	254.0	136.5

Fruit size classification:

According to fruit size classification, the extra and class 1 fruit ratio increased as the applied water irrigation increased for both irrigation systems, but class 1 fruit ratio decreased after SET_{75} for surface irrigation, Table 5. The highest extra and class 1 fruit ratios were obtained with DET_{100} treatment for drip irrigation, while RET34.75 treatment indicated the lowest values. The highest ratio of class 2 fruits was noted with surface irrigation treatment SET_{100}.

Table 5: Fruit size classification under different water regimes (%)

Treatments	Extra	Class 1	Class 2	Other
SET_{50}	4.5	9.1	50	36.4
SET_{75}	6.8	18.2	56.8	18.2
SET_{100}	11.4	9.3	61.1	18.2
DET_{50}	5.5	18.2	40	36.3
DET_{75}	20	34.5	45.5	0
DET_{100}	36.2	36.5	27.3	0
RET34.75	0.9	8.2	36.4	54.5

Extra (>75 mm), class 1 (68–75 mm), class 2 (60–68 mm), other (<60 mm), [19].

The highest extra and class 1 fruit ratios were identified with drip irrigation treatments during the study. Surface irrigation treatment showed the lowest values. It has been identified that transition from surface irrigation method to drip irrigation increases the fruit size, which is an important marketing criterion for apple growing. In order to obtaining the highest fruit size will be possible when DET_{100} treatment is used.

Firmness of apple fruit:

Flesh firmness values decreased as the amount of water irrigation increased with both drip and surface irrigation treatments during the study as shown in Fig 5. For surface irrigation treatments, the values of apple fruit firmness were higher if compared with drip irrigation treatments. The firmnesses were 7.86, 6.26 and 6.18 kg/cm^2 for treatments SET_{50}, SET_{75}, and SET_{100} respectively in case of surface irrigation and were 6.93, 6.11 and 6.10 kg/cm^2 for treatments DET_{50}, DET_{75}, and DET_{100} respectively in case of drip irrigation. In accordance with these results, Albanese, Drake, Roth, et al., [Albanese, et al., 2007; Drake, et al., 1988; Roth, et al., 2007], reported that firmness was reduced at a water content decrease in fruit.

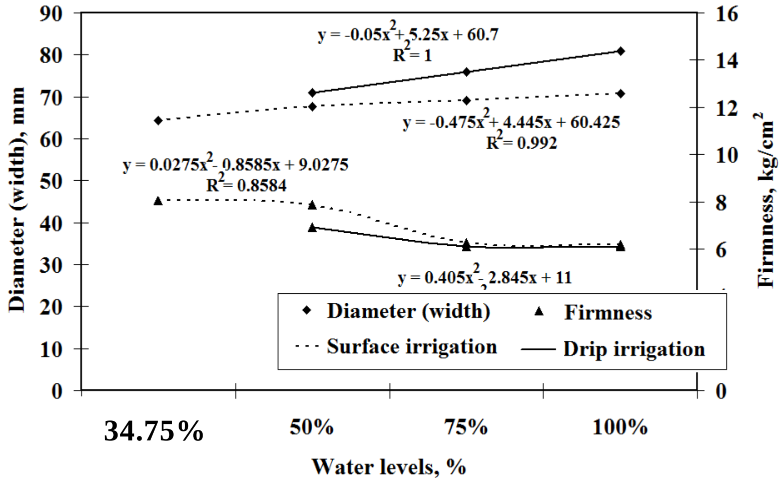

Fig. 5: Firmness and diameter of apple fruit at different water regimes.

The highest value was found in RET34.75 (8.05 kg/cm^2) treatment of traditional irrigation comparing with drip and surface irrigation. DET_{100} treatment represented the lowest flesh firmness (6.1 kg/cm^2). An inverse relationship was identified between flesh firmness and applied water irrigation. In other hand, flesh firmness decreased as fruit length, diameter (width), thickness, mass and volume increased, Tables 3 and 4. There were significant polynomial relationships for firmness, diameter and both irrigation systems, Fig. 5.

Total soluble solids (TSS):

Results of TSS measurements are presented in Table 3 and Fig. 6. For surface irrigation system, TSS was 15.7, 13.9 and 13.5% for treatments SET_{50}, SET_{75} and SET_{100}, respectively and the corresponding total TSS productivity was 1.361, 1.275 and 1.241 ton/fed. For drip irrigation system, TSS was 15.8, 13.8 and 13.6% for treatments DET_{50}, DET_{75} and DET_{100}, respectively and the corresponding total TSS productivity was 1.375, 1.507 and 1.551 ton/fed. Even though RET34.75 treatment had the highest TSS (16.3%), but had the lowest total TSS productivity (1.213 ton/fed).

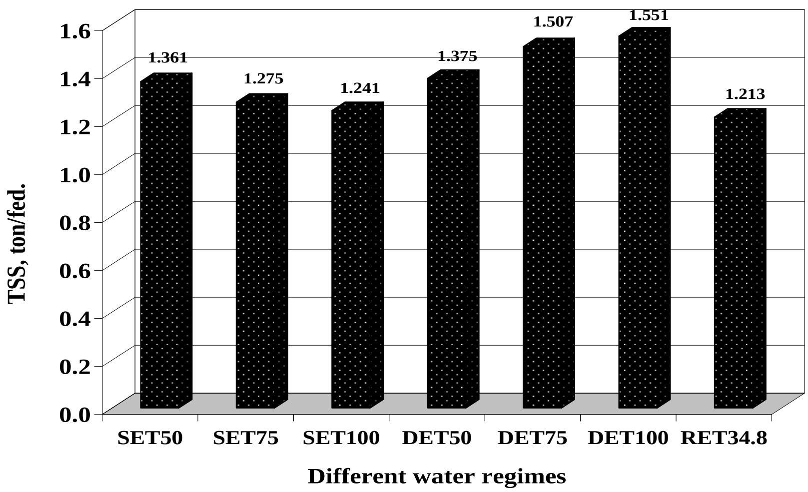

Fig. 6: Total productivity of soluble solids of apple fruits at different irrigation regimes.

The fruit sugar content:

Results of sugar content measurements are presented in Table 3 and Fig. 7. For surface irrigation system, sugar content was 14.5, 13.5 and 13.4% for treatments SET_{50}, SET_{75} and SET_{100}, respectively and the corresponding total sugar productivity of sugars was 1.257, 1.238 and 1.231 ton/fed. For drip irrigation system, sugars content was 12.7, 12.5 and 12.1% for treatments DET_{50}, DET_{75} and DET_{100}, respectively and the corresponding total sugar productivity of sugars content was 1.105, 1.365 and 1.380 ton/fed. For RET34.75 treatment, the sugar content was 15.3% and the corresponding total productivity of sugars was 1.139 ton/fed.

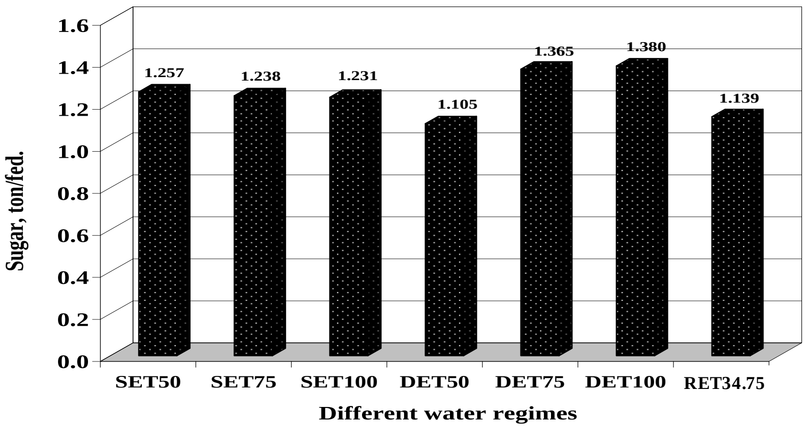

Fig. 7: Total productivity of sugars content of apple fruits at different irrigation regimes.

The results showed that the total sugar and TSS productivities decreased with increasing water irrigation in surface irrigation system, while the total sugar and TSS productivities increasing with increase water irrigation in drip irrigation system. This is due to differences in production in relation to treatments of surface irrigation opposite of what happens in drip irrigation treatments.

4. CONCLUSION:

Experiment was done during the 2011/2012 growing season in a commercial apple (double red delicious) orchard (spacing 5×5 m) in Raaseltorab – El-Bayda (Libya) to investigate the effect of surface and drip irrigation systems on yield and quality of apple fruits under three water levels (100% ET_c, 75% and 50%). The water requirement (100% ET_c) was calculating by FAO Penman–Monteith equation according to climatic conditions of area (1975 to 2012). The quality parameters that investigated are Fruit length, thickness, diameter (width), weight, volume, fruit size classification, firmness, TSS and sugar according to UNECE standard [5, 6].

The results showed that:

1. Calculated water irrigation requirements by FAO Penman–Monteith equation was 1580 mm/season, which present (100% ET_c) the treatments SET_{100} and DET_{100}.

2. The gross yields per tree and mean fruit weights were increased by increasing water irrigation applied for both surface and drip irrigation systems. The maximum gross yield per tree and fruit weight were 67.9 kg and 216.3 g for same treatment DET_{100} while the minimum values were 49.3 kg and 121.6 kg for same treatment RET34.75.
3. The water use efficiencies (WUE) were deceased by increasing water irrigation applied for both surface and drip irrigation systems. The maximum WUE was 3.22 kg/m^3 for treatment RET34.75 while the minimum value was 1.38 kg/m^3 for treatment SET_{100}.
4. The moisture content was increased by increasing water irrigation applied for both surface and drip irrigation systems. The maximum moisture content was 86.7 % for treatment DET_{100} while the minimum value was 81.4 % for treatment SET_{100}.
5. The fiber content was decreased by increasing water irrigation applied for both surface and drip irrigation systems. The maximum fiber content was 6.2 % for treatment RET34.75 while the minimum value was 3.8 % for treatment DET_{100}.
6. The fruit firmness was decreased by increasing water irrigation applied for both surface and drip irrigation systems. The maximum fruit firmness was 8.05 kg/cm^2 for treatment RET34.75 while the minimum value was 6.1 kg/cm^2 for treatment DET_{100}.
7. The fruit total soluble content (TSS) was decreased by increasing water irrigation applied for both surface and drip irrigation systems. The maximum TSS was 16.3% for treatment RET34.75 while the minimum value was 13.5 % for treatment SET_{100}.
8. The fruit sugar content was decreased by increasing water irrigation applied for both surface and drip irrigation systems. The maximum fruit sugar content was 15.3% for treatment RET34.75 while the minimum value was 12.1 % for treatment DET_{100}.
9. The TSS and sugar productivities were increased by increasing water irrigation applied for both surface and drip irrigation systems. The maximum TSS and sugar productivities were 1.551 and 1.38 ton/fed. for same treatment DET_{100} while the minimum values were 1.213 and 1.139 ton/fed. for same treatment RET34.75.
10. According to the results of the study, it is concluded that transition from surface irrigation to drip irrigation method have positive

effects on yield and fruit quality of apple trees which had previously been irrigated by rainfall for many years.

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تأثير أنظمة مائية على إنتاجية وجودة ثمار التفاح في المناطق شبة الجافة – ليبيا

أحمد محروس حسن

قسم الهندسة الزراعية – كلية الزراعة – جامعة القاهرة – مصر

يهدف هذا البحث إلى دراسة تأثير نظامي الري السطحي (S) والري بالتنقيط (D) على جودة ثمار التفاح صنف Double red delicious تحت ثلاثة مستويات مياه ري مختلفة في المناطق شبة الجافة وهي ET1 وتمثل ١٠٠٪ من الاحتياجات المائية المطلوبة لشجر التفاح وET2 تمثل ٧٥٪ وET3 تمثل ٥٠٪. تم حساب الاحتياجات المائية الفعلية بناء على الظروف المناخية الخاصة بالمنطقة باستخدام معادلة (Penman–Monteith). تم أخذ عينات ثمار التفاح من كل معاملة لإجراء بعض القياسات وخواص الجودة القياسية طبقا للمواصفات القياسية لـ (UNECE 2007 and 2011). وقد بينت الدراسة ان الاحتياجات المائية لشجرة التفاح ١٥٨٠ مم/موسم والتي تمثل (100% ETc) المعاملة SET100 والمعاملة DET100. كانت أقصى كتله لثمار التفاح (٢١٦.٣ جرام) وأقصى إنتاجية لشجرة التفاح (٦٧.٩ كجم) لنفس المعاملة DET100. نقصت كفاءة الاستخدام المائي بزيادة كمية المياه المضافة في كلا من نظامي الري السطحي والري بالتنقيط. وكانت أقصى كفاءة للاستخدام المائي (٣.٢٢ كجم/م٣) للمعاملة RET34.8. زاد المحتوى الرطوبي للثمرة بزيادة كمية المياه المضافة في كلا من نظامي الري السطحي والري بالتنقيط. وكان أقصى محتوى رطوبي للثمرة (٨٦.٧٪) للمعاملة DET100. نقص محتوى الثمرة من الألياف بزيادة كمية المياه المضافة في كلا من نظامي الري السطحي والري بالتنقيط. وكان أقصى محتوى للألياف للثمرة (٦.٢٪) للمعاملة RET34.8. زيادة التصنيف الحجمي لثمار التفاح بالنسبة إلى الفئة اكسترا والفئة ١ بزيادة كمية المياه المضافة في كلا من نظامي الري السطحي والري بالتنقيط. حيث كانت أعلى نسبة للمعاملة DET100. نقصت صلادة (Firmness) ثمار التفاح بزيادة كمية المياه المضافة في كلا من نظامي الري السطحي والري بالتنقيط. وكانت أقصى صلادة لثمار التفاح (٨.٠٥ كجم/سم٢) للمعاملة RET34.8. نقصت نسبة المواد الصلبة الذائبة (TSS) لثمار التفاح بزيادة كمية المياه المضافة في كلا من نظامي الري السطحي والري بالتنقيط. وكانت أقصى نسبة للمواد الصلبة الذائبة (١٦.٣٪) للمعاملة RET34.8. نقصت نسبة السكر لثمار التفاح بزيادة كمية المياه المضافة في كلا من نظامي الري السطحي والري بالتنقيط. وكانت أقصى نسبة للسكر لثمار التفاح (١٥.٣٪) للمعاملة RET34.8. زيادة إنتاجية كلا من المواد الصلبة الذائبة (TSS) والسكر لثمار التفاح في الفدان بزيادة كمية المياه المضافة في كلا من نظامي الري السطحي والري بالتنقيط وكانت أقصى إنتاجية للمواد الصلبة الذائبة والسكر ١.٥٥١ و ١.٣٨ طن/فدان على التوالي لنفس المعاملة DET100.

الكلمات المفتاحية: الري السطحي وبالتنقيط، إنتاجية التفاح، كفاءة استخدام المياه، قياسات الجودة.