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COMPARATIVE STUDY ON THE EFFECT OF CHANGE THE SURFACE IRRIGATION TO BUBBLER IRRIGATION SYSTEMS OF FRUITFUL "LE-CONTE" PEAR TREES

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ABSTRACT

The present investigation was carried out during the two successive seasons of 2011 and 2012 to evaluate the water use efficiency, vegetative and roots growth parameters, fruiting measurements, fruit quality and leaf mineral content of "Le-Conte" pear trees under the two irrigation systems.

Obtained results revealed that, the surface irrigation gave the highest consumptive use followed by bubbler irrigation system. As it registered (6590 and 3311 m^3/fed.) in the first season and (6398 and 3308m^3/fed.) in the second one, respectively. Water consumption increased as soil moisture maintained high by surface irrigation. Monthly water use was low after February, then increased to reach a maximum during June and July then they declined again. On the other hand, bubbler irrigation system achieved an increase of water use efficiency.

Data displayed obviously that, bubbler irrigation system obtained an increase in both vegetative and root growth parameters i.e., (shoot length, number of leaves/shoot, leaf area, root length, number of roots and dry weight). However, bubbler irrigation system resulted in significantly increase in fruiting parameters (fruit set %, number of fruits/tree and yield either kg per tree or ton/fed.). In addition to that, most of both physical and chemical studied fruit characteristics were improved by using bubbler irrigation system than the surface irrigation system during 2011 and 2012 seasons. Meanwhile, and leaf mineral content (N, P, and K) was insignificantly affected by both investigated irrigation systems in the two seasons of study.

Finally, it could be concluded and recommended for pear growers on clay loamy soil to change surface irrigation system to bubbler irrigation system for save irrigation water with better fruit yield, fruit quality, longer root system and increasing water use efficiency.

INTRODUCTION

Water is consumed plentifully for agricultural purposes in Egypt and in the world (approximately 80%). Water for agriculture in Egypt is becoming a major constraint therefore maximizing its use can be carried out through the efficiency of modern irrigation systems (Brown, 1999).

Nevertheless, the rate of water consumption for industrial and domestic needs is gradually increasing and rate of water consumption for agricultural irrigation is decreasing (Önder *et al*., 2005) that necessitate a more efficient use of available water resources. Consequently, irrigation systems with a contribution on saving water (drip irrigation system, etc.) should be used more. Surface irrigation systems (surface irrigation, etc.) have been used extensively in fruit growing, and transition to drip irrigation system has started being preferred more in recent years. These new systems are capable of delivering water in controllable small quantities as after and as long as needed. On the other hand, maximizing the use of modern irrigation systems became essential to increase water demand

(Brown, 1999) especially in arid and semiarid regions as Egypt where population is fast increasing. Because drip irrigation system offers certain advantages such as fruit quality, decreasing labour costs, saving irrigation water, etc., many fruit growers have adopted this method. The adoption of drip irrigation system has expanded further especially at the regions with limited water resources.

Therefore, the effects of changing the irrigation system on fruit quality, vegetative growth and yield should be examined and an irrigation schedule should be designed. Drip irrigation system has been preferred for irrigation apple orchards in the recent years. Virtually, the plant response to water logging can be traced back to the limitation of oxygen diffusion to the roots. The use of modern irrigation system is essential for the reduction of irrigation water demands (Brown, 1999).

The drip irrigation increased the beneficial use of water, enhanced plant growth and yield, reduced salinity hazard, improved application of fertilizer limited weed growth and decreased energy required. Seasonal water requirements values for deciduous orchards were 7420 m^3/fed/year for almond, apple, apricot, peach, pear, pecan and plum while were 5607 m^3/fed/year for fig and grape. Salem *et al*., (1999), Fathi (1999 a and b), Ismail *et al*., (2007) on pear showed that, the minimum growth parameters and yield components were gained with irrigation at 80 % F.C.

The main objective of this study was to identify the effects of transition from surface irrigation to bubbler irrigation on pear fruit quality, vegetative growth, root system growth and water use efficiency.

MATERIALS AND METHODS

This study was conducted at the private farm at Giza during the two growing seasons 2011 and 2012, respectively, in addition to a preparation season during 2010. The main target of this investigation is to study the effect of changing the irrigation system from surface to the modern irrigation system (Bubbler irrigation) on vegetative growth, yield, fruit quality and some water relations of pear "Le-Conte" trees budded on "*Pyrus betulaefolia*" and grown at 5 x 5 apart trees 8 years old. The experimental soil (loamy clay) was analyzed, Table (1) according to Piper (1950) and Jackson (1958).

The field capacity, the permanent wilting point, the available water and bulk density were determined as well as another physical soil analysis as shown in Table 1. Meteorological data for the Agricultural Research Station are shown in Table 2.

Irrigation was done when the soil moisture reached the relevant level to determine available soil water retained in the soil. Soil moisture was determined grave metrically on oven dry basis of soil samples taken to a depth of 15 cm. up to 60 cm. water consumptive use calculated for each irrigation treatments used in this study.

Application amounts of irrigation water were equal to 70% from the Doorenbos-Pruitt equation, Table 3. pear trees which had been irrigated by surface irrigation for many years was used for the study, while bubbler irrigation was applied in one section, and surface irrigation was continued for rest of the pear orchard.

Table (1): Physical properties of the orchard soil.

Parameter				Value
Particle size distribution (%):				
Clay %				34.4
Silt %				56.4
Fine sand %				8.20
Coarse sand %				1.0
Texture class				Clay loam
Water parameters and bulk density				
Depth	**Field capacity (FC) % (w/w)**	**Wilting Point (WP) % (w/w)**	**Available water (AW) % (w/w)**	**Bulk density (BD) gm./cm^3**
0-15	39.80	18.62	21.18	1.15
15-30	33.71	17.48	16.23	1.24
30-45	30.91	16.91	13.28	1.21
45-60	29.12	16.50	12.62	1.28

Table (2): Meteorological data in 2011 and 2012 seasons.

Season	**2011**							**2012**						
Month	**T.max**	**T.min.**	**W.S**	**R.H.**	**S.S**	**S.R**	**R.F**	**T.max**	**T.min.**	**W.S**	**R.H.**	**S.S**	**S.R**	**R.F**
Jan.	21.2	9.7	0.9	68.3	10.3	280	0.6	19.2	8.3	1.4	61.0	10.4	280	2.6
Feb.	22.9	11.3	1.3	56.7	11.0	354	0.7	20.7	9	1.4	59.3	11.0	354	0.4
Mar.	24.8	11.9	1.8	57.3	11.8	441	0.4	23.6	11.3	1.8	60.7	11.8	441	0.0
Apr.	28.4	18.5	1.4	51.0	12.8	519	0.4	30.7	15.9	1.8	50.7	12.8	519	0.0
May	32.8	18.7	1.7	50.3	13.5	585	0.1	34.2	20	1.6	50.7	13.5	585	0.2
Jun.	35.2	21.7	2.0	54.7	13.9	627	0.0	36.9	23.5	1.5	55.3	13.9	627	0.0
Jul.	37.3	23.5	1.9	58.7	13.8	613	0.0	37.6	25.3	1.0	64.0	13.6	613	0.0
Aug.	36.5	23.9	1.6	61.5	13.2	577	0.0	37.7	24.8	1.5	58.7	13.1	577	0.0
Sep.	35.5	22.7	0.9	58.0	12.2	512	0.0	34.9	22.1	1.8	55.3	12.2	512	0.0
Oct.	33.0	20.3	1.0	59.3	11.3	417	0.0	33	20.6	1.5	62.3	11.3	417	0.0
Nov.	26.9	15.6	0.9	70.7	10.5	326	0.0	27.4	16.1	1.2	67.7	10.5	326	0.0
Dec.	22.7	11.7	1.2	65.3	10.1	268	0.0	22.8	10.2	0.9	75.3	10.1	268	0.0

where: T.max., T.min.= maximum and minimum temperatures °C; W.S = wind speed (m/sec); R.H.= relative humidity (%); S.S= actual sun shine (hour); S.R= solar radiation (cal/cm^2/ day). RF = rainfall (mm / month).

[Data were obtained from the agrometeorological Unit at SWERI, ARC]

Table (3): Doorenbos-Pruitt formulae in 2011 and 2012 seasons.

Season		**Doorenbos- Pruitt**			
		2011		**2012**	
Month	**Kc**	**mm/day**	**mm/month**	**mm/day**	**mm/month**
January	0.30	1.99	61.69	1.91	59.21
February	0.40	2.81	78.68	1.99	55.72
March	0.55	3.62	112.22	3.55	110.05
April	0.70	4.56	136.80	4.82	144.60
May	0.78	5.61	173.91	5.70	176.70
June	0.83	6.26	187.80	6.27	188.10
July	0.95	6.21	192.51	6.10	189.10
August	0.83	5.71	177.00	5.80	179.80
September	0.78	4.91	147.30	5.0	150.00
October	0.75	3.88	120.28	3.89	120.59
November	0.70	2.65	79.50	2.70	81.00
December	0.60	1.97	61.07	1.96	60.76
Seasonal (mm)			1529		1516

Irrigation treatments:

The adopted experimental treatments were arranged as a complete block design with four replicates. The treatments were:

1- Surface irrigation system.

2- Bubbler irrigation system.

1. Calculation of water consumptive use (CU):

Water consumptive use was calculated for each irrigation using the following formula (**Israelsen and Hansen, 1962**).

$$CU = \sum_{i=1}^{i=4} D_i \times Bd_i \times \frac{Q_2 - Q_1}{100}$$

Where: CU = Consumptive use (mm.)

D = The depth (in mm) of the irrigated soil under consideration.

Bd = Bulk density (gm/cm^3) of the soil in the relevant soil depth.

Q_2 = Percentage of moisture after irrigation.

Q_1 = Percentage of soil moisture before next irrigation.

Bubbler irrigation system

The bubbler irrigation system used in the farm includes an irrigation pump (50 hp) connected to sand and screen filters and a fertilizer injector tank. The conveying pipeline system consists of a main line that is made of PVC pipe of 76.2 mm diameter connected to sub-main line of 50.8 mm and manifold of 38.1 mm. The bubbler lateral lines of 16 mm diameter are connected to the manifold line. Each tree line is served by two lateral lines about 150 cm apart (i.e., 0.75 m from each side of the pseudo stems). Lateral lines equipped with build-in bubblers of 60 l/h discharge were spaced 2 m apart on the 2 bubblers.

Amount of applied irrigation water (AIW):

1.1. Reference evapotranspiration (ETo):

Reference evapotranspiration (ETo) was calculated using the meteorological data as cited by Doorenbos and Pruitt, (1977) and Allen *et al.,* (1998) as follows: -

Doorenbos–Pruitt (1977) adapted the radiation formula to predict potential evapotranspiration as follows:

ETp = bw Rs/L- 0.3

Where: ETp = Daily potential evapotranspiration (mm/day).

b = Adjustment factor based on wind and mean relative humidity.

W = Weighting factor based on temperature and elevation above sea level.

Rs = Daily total incoming solar radiation for the period of consideration (cal/cm^2/day).

L = Latent heat of vaporization of water (cal/ cm^2/ day)

Factors (b) and (w) could be obtained from the tables cited by (Doorenbos and Pruitt 1977).

The water requirements were calculated by meteorological parameters using CROPWAT computer model (FAO 1992), based on calculation using Doorenbos and Pruitt equation and the Kc values illustrated in FAO-24 (Allen *et al al*., 1998).

$$\text{Applied water} = \frac{\text{ETc}}{\text{Ea}}$$

Where:

ET_c: water consumptive use

E_a : application efficiency (fraction)

3. Water use efficiency (WUE):

Water use efficiency (WUE) is used to describe the relationship between production and the amount of water consumed. It was determined according to the following equation Jensen (1983):

$$\text{W.U.E} = \frac{\text{Fruits yield (kg)/feddan}}{\text{Seasonal ET (m}^3\text{/water consumed) /feddan}}$$

The following measurements were recorded:

A- Growth parameters: shoot length, number of leaves/shoot and leaf area at mid August of both studied seasons.

B- Percentage of fruit set: the total number of flowers at full bloom and set fruitelts were counted on each tagged branch, then the fruit set % was estimated according to Westwood (1978) as follows:

$$\text{Fruit set (\%)} = \frac{\text{Number of set fruitlets}}{\text{Total of flowers at full bloom}} \times 100$$

C- Fruit quality: at picking date, samples of 9 random matured fruits/replicate were used to assess fruit quality as fruit weight and size, fruit dimensions (length and diameter), fruit firmness (using lb/inch^2 pressure tester), juice TSS content (using hand refractometer), juice acidity (expressed as gram of malic acid/100 ml. juice) and TSS/acid ratio.

D- Root distribution:

Soil samples were taken in November 2012 at 0-30, 30-60 and 60-90 cm depth at 100 and 200 cm from the tree trunk in the four directions. Root length (< 2, 2-6 and > 6 mm root thick) was assessed (cm) and root dry weight (g.) as g./hole (1.628 kg soil or 1750.8 cm^3) according to Cahoon *et al*., (1959).

E- Leaf nutrient analysis included N by the micro-Kjeldahl digestion method as described by Pregl (1945), and K using wet digestion Piper (1950) and the Flame photometer method according to Brown and Lilleland (1946). Total phosphorus content was determined using a Spekol spectrophotometer at 882.0 uv according to the method described by Murphy and Riely (1962).

Statistical analysis:

All the obtained data during the two seasons of the study were subjected to analysis of variance method according to Snedecor and Cochran (1980). Meanwhile, differences among means were compared using Duncan's multiple range test at 5 % level (Duncan, 1955).

RESULTS AND DISCUSSION

A- Pear trees water relations parameters:

A-1. Applied irrigation water:

Seasonal applied irrigation water by pear trees decreased under bubbler irrigation as compared with surface irrigation in both seasons. As it registered 3311 and 6590 m^3 in the first season and 3308 and 6398 m^3 in the second season, respectively (Table 3). Such results might be reasonable, since more frequent irrigation period provide high evaporation opportunity from the relatively surface irrigation rather than bubbler irrigation. The seasonal water use values were obtained from the sum of water consumptive use for all irrigations per treatment, divided by the irrigation efficiency from January until December in each season.

Table (3): Monthly and seasonal applied irrigation water to pear trees by irrigation system in 2011 and 2012 growing seasons.

Season	Bubbler irrigation				Surface irrigation			
	2011		2012		2011		2012	
Month	m^3/ day	m^3/ month	m^3/ day	m^3/ month	m^3/ day	m^3/ month	m^3/ day	m^3/ month
January	1.8	54.4	1.7	52.2	-	-	-	-
February	3.3	92.5	2.3	65.5	-	-	-	-
March	5.9	181.5	5.7	178.0	12.7	395	10.5	327
April	9.4	281.5	9.9	297.6	23.5	705	24.9	748
May	12.9	398.8	13.1	405.2	28.2	873	24.9	771
June	15.3	458.3	15.3	459.0	31.2	936	28.8	863
July	17.3	537.7	17.0	528.2	35.2	1091	32.1	994
August	13.9	431.9	14.2	438.7	30.7	952	31.1	964
September	11.3	337.8	11.5	344.0	27.6	827	29.9	898
October	8.6	265.2	8.6	265.9	16.5	513	17.6	547
November	5.5	163.6	5.6	166.7	9.9	298	9.5	286
December	3.5	107.7	3.5	107.2	-	-	-	-
Seasonal (m^3/fed.)		**3311**		**3308**		6590		6398

A-2. Monthly applied irrigation water.

Monthly applied irrigation water values by pear trees were obtained from daily water use multiplied by the number of days in one month. It began to raise during March then, ET value gradually increased to reach its maximum at early summer during June and July Fig.1. This might be due to the increase in growth during summer months afterwards, the daily applied irrigation water, again, gradually decreased. Such pattern was attained by pear trees, regardless of factors studied. In this concern During April and early May little growth will appear, but towards the end of October the trees slow down into steady progress. Similar results were obtained since water management practices resulted in maximum yield, and trees growth depending on crop load and yearly climatic change. There was increase in transpiration and water uptake from summer to autumn followed by a decrease until spring.

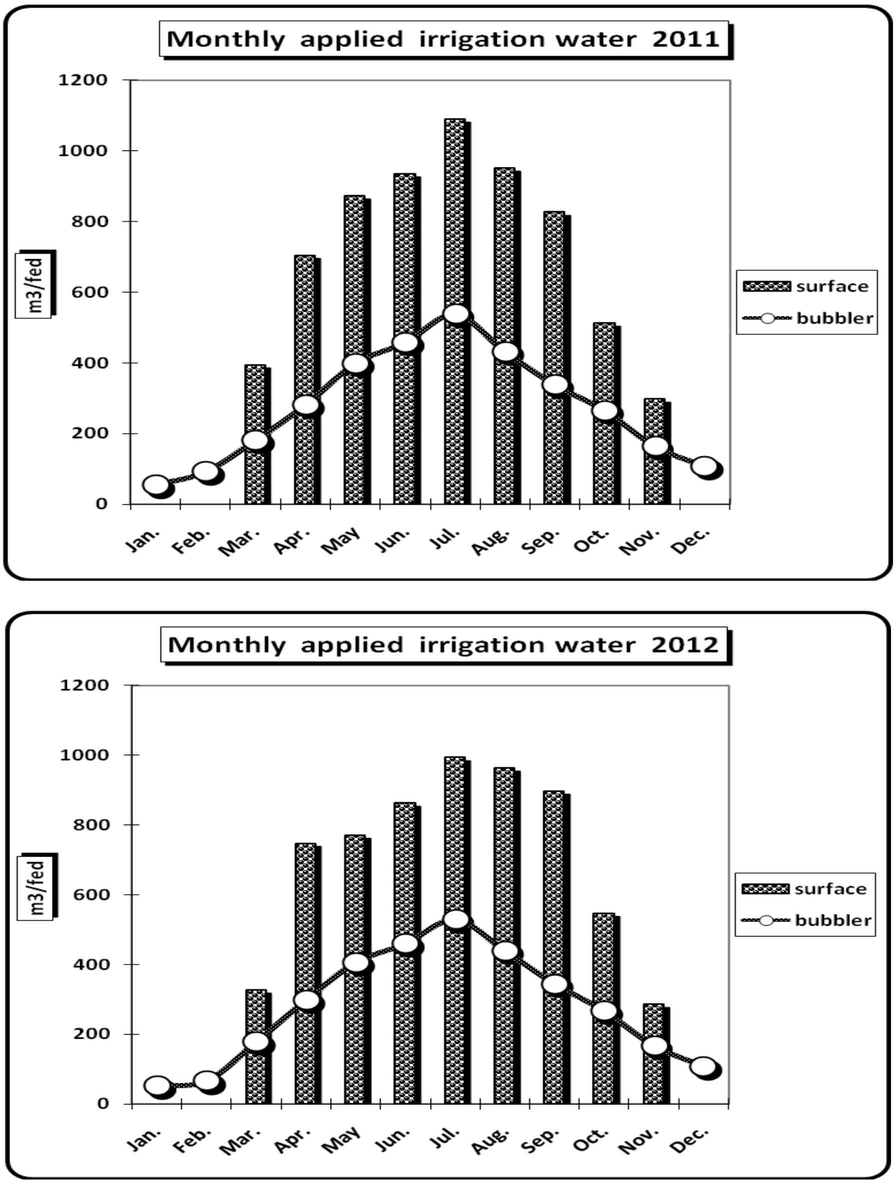

Fig. 1, Monthly applied irrigation water to pear trees by irrigation system in 2011 and 2012 growing seasons.

A-3. Water use efficiency

Water use efficiency, is used to show the yield (kg.) per unit of water unit required in evapotranspiration. It appears from Fig. 2 that this trait was markedly profitable under bubbler Irrigation as it registered (4.43 yield kg/m^3) water consumed, while decreased by surface irrigation which resulted to (1.37 kg/m^3) water consumed, as average of two seasons of study, respectively.

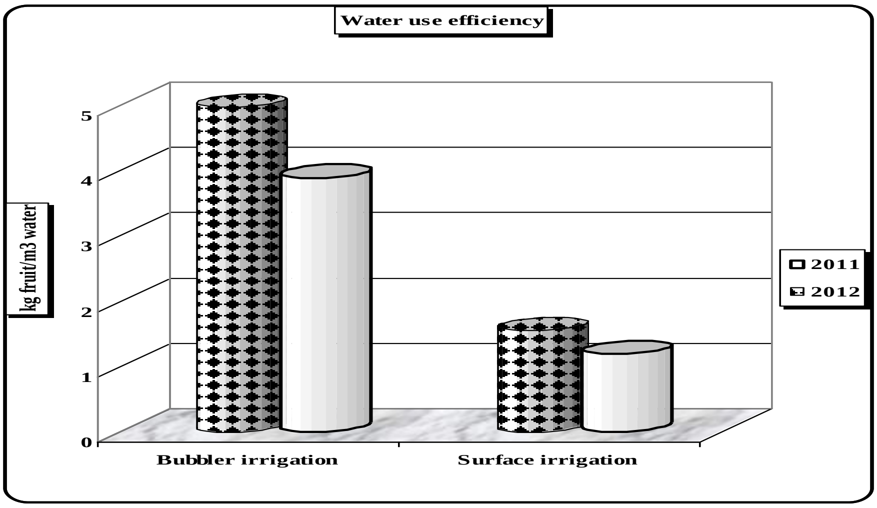

Figure 2, Effect of bubbler irrigation and surface irrigation on water use efficiency (WUE) kg/m^3 of pear trees.

B- Tree growth:

B-1. Vegetative growth measurements:

Data presented in Table (3) shows the effect of irrigation systems on some vegetative growth parameters of "Le-Conte" pear trees as expressed by shoot length, number of leaves per shoot and leaf area during both 2011 and 2012 seasons.

Concerning the shoot length (cm.), it is obvious that trees irrigated with bubbler irrigation system caused higher shoot length growth parameter (the longest shoots) in both seasons. However, trees irrigated with surface irrigation system showed the lowest values and shortest shoot length in relation to the other irrigation system. In spite of that, differences were significant when compared to each other in the second season only.

With respect to number of leaves/shoot, it is clear that, trees irrigated by surface irrigation system exhibited significantly the lowest number of leaves per shoot. On the other hand, the greatest number of leaves per shoot was produced from trees irrigated with bubbler irrigation system. Such trend was true during both growing seasons of study.

In regard to leaf area (cm^2) of "Le-Conte" pear trees, it is quite evident that, trees irrigated with bubbler irrigation system induced leaves of larger surface area in both seasons as compared to those irrigated by surface irrigation system. Meanwhile, differences between the two irrigation systems under study were insignificant. Such trend was detected during both 2011 and 2012 seasons of study.

According to the results of vegetative growth measurements, differences were determined among all treatments, but a clear relationship could not be identified. It is clear that transition from surface irrigation to bubbler irrigation system has positive effects on vegetative growth of pear trees. Plants spend most of their energies while taking water from the soil by their roots (Kocacaliskan, 2005).

Because, the irrigation interval is long during surface irrigation and the soils water decreases continuously after irrigation, roots of trees spend most of their energies during water in take and spend less energy for growth and development. In bubbler irrigation, as the soil is more humid due to frequent irrigation interval the trees do not spend much energy while taking water from the soil. They spend most of their energies for growth, development, productivity and fruit quality. Therefore, the vegetative growth of bubbler irrigation treatments was positively influenced. Examination of shoot length, leaf area and number of shoot suggests an increase during bubbler irrigation compared to those of surface irrigation. The reason of the increase in these values is the positive impact on vegetative growth. Similarly, Safran *et al*., (1975) pointed out that fruit trees which had been irrigated for many years with surface irrigation systems did not indicate any reduction in vegetative growth after switching to bubbler irrigation, and bubbler irrigation had a positive effect on vegetative growth. Some researches reported that different irrigation schedules on plum and pistachio trees and different irrigation systems on lemon trees had no effects on vegetative growth (Yidirim and Yidirim, 2005).

Table (3): Shoot length, number of leaves/shoot and leaf area of "Le-Conte" pear trees in response to both surface irrigation system and bubbler irrigation system during both 2011 and 2012 seasons.

Irrigation system	Shoot length (cm.)		No. of leaves/ shoot		Leaf area (cm^2)	
	2011	2012	2011	2012	2011	2012
Bubbler irrigation	56.6a	56.85a	29.20a	30.10a	38.82a	39.50a
Surface irrigation	55.3a	50.30b	26.33b	25.87b	38.32a	38.87a

B-2. Length and number of roots:

Data obtained in Tables (4 & 5) revealed clearly that, the response of the average root length and number of roots (fine = less that 2 mm in diameter, medium = from 2 to 6 mm and large = > 6 mm in diameter) root at (100 & 200 cm) distances from the tree trunk under different depths through the soil profile (0-30; 30-60 and 60-90 cm) from the soil surface under the effect of both bubbler irrigation system and surface irrigation system followed a similar trend during this study. However, roots with different diameters either at horizontal or vertical directions were significantly increased with bubbler irrigation system than the other irrigation system (surface). Also, it was observed that, roots were concentrated around the trunk and around the bubbler (100 cm from tree trunk) especially at 0-30 cm in depth. On the other hand, the majority of root system is the fine roots (< 2 mm) while > 6 mm roots extended only to (100 cm) from the tree trunk.

Furthermore, data in Table (6) displayed obviously dry weight of roots of "Le-Conte" pear trees at (100 & 200 cm) distances from the tree trunk as well as at (0-30, 30-60 & 60-90 cm) depths from the soil surface as affected by both bubbler and surface irrigation systems that, root dry weight significantly and gradually reduced as irrigation system was decreased with increasing the distance from the tree trunk i.e., (2.9 to 2.2; 2.89 to 2.48 and 28.96-3.87 g., respectively). Whereas, the reduction of root dry weight was pronounced with increasing the depth of the soil surface (3.01, 2.44 and 2.21; 2.85; 2.98 and 2.23 to 19.01, 11.43 and 18.81 g., respectively).

4-5

However, root distribution depends up on the volume of wetted soil, which was related to soil hydraulic conductivity as well as the rate and duration of water application (Levin *et al*., 1980). While, reducing the size of the root zone had decreased the size of root system and caused a decrease in water consumption (Magriro, 1981). Meanwhile, root length was significantly and negatively affected with water stress and highest decrease occurred when the available soil water decreased from 40 to 20 % (Abo-Taleb, Safia *et al*., 1998, Hussein, 1998, Fathi, 1999b, Salem *et al*., 1999, Ibrahim, 2001 and El-Gendy, 2002).

These results may support the phenomenon that water stress reduced root distribution and soil dryness significantly reduced root dry matter production. The present results also showed that the average dry weight of large roots (> 6 mm) was considerably bigger than both fine (< 2 mm) and medium (2-6 mm) roots specially at 0-30 and 30-60 cm deep soil as well as 100 cm from tree trunk. Moreover, Marler and Davies (1990) stated that dry weight significantly reduced at irrigation low level whereas more than 90 % of roots was with 80 cm from the trunk. Also, Fathi (1999b) and Salem *et al*., (1999) indicated that water stress decreased root densities at shallow soil depths. While, Goode and Hyryez (1964) said that, irrigation increased root weight at 0-15 cm but reduced it at 15-30 cm depth.

B-3. Fruiting parameters

Data tabulated in Table (7) indicated the response of tree flowering of "Le-Conte" pear cultivar as expressed by fruit set percentage, tree yield as either kg/tree or ton per faddan and number of fruits per tree as affected by irrigation systems i.e., surface irrigation and bubbler irrigation system during both 2011 and 2012 seasons, respectively.

Referring to the percentage of fruit set, it is clear from data presented in the last Table (7) that, in the two seasons of study, trees irrigated with bubbler irrigation system was the most effective irrigation system to increase fruit set percentage than the corresponding ones of surface method. Differences between the two irrigation systems were significant during both the first and second seasons of study.

With respect to tree yield as calculated by number of fruits per tree, it is quite clear from data tabulated in the same abovementioned Table that, a significant increase was noticed in fruit number per tree for trees irrigated with bubbler irrigation system than the analogous ones of trees irrigated by surface irrigation system. Such trend was true during both 2011 and 2012 seasons.

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Considering yield as kg. per tree, it is interesting to notice from data in Table (7) that, in both 2011 and 2012 seasons of study, trees irrigated with bubbler irrigation system, mainly in the second season produced significantly higher yield per tree than the corresponding ones of trees which irrigated under surface irrigation system.

As for yield expressed as ton per faddan, it could be observed from data tabulated in the same aforesaid Table (7) that, the same previously effect was obtained in both the first and second seasons when yield (ton/faddan) was concerned. In other words, trees irrigated with bubbler irrigation system yielded greater amounts of fruit crop than those of trees irrigated by surface irrigation system. Moreover such trend was detected during the two seasons of study.

Table (7): Fruit set (%), number of fruits/tree yield as either kg/tree or ton/fed. of "Le-Conte" pear trees in response to both surface irrigation system and bubbler irrigation system during both 2011 and 2012 seasons.

Irrigation system	Fruit set (%)		No. of fruit/tree		Yield (kg/tree)		Yield (ton/fed.)	
	2011	2012	2011	2012	2011	2012	2011	2012
Bubbler irrigation	7.54a	7.15a	456.7a	506.7a	76.56a	98.00a	12.87a	16.46a
Surface irrigation	7.08b	6.90b	390.0b	420.0b	47.13b	63.17b	7.92b	10.53b

C- Fruit properties:

C-1. Fruit physical properties:

C-1-1. Fruit weight and fruit size:

With respect to the average fruit weight (g.) and fruit size (ml^3) as affected by the both irrigation systems under study, data in Table (8) indicated that, "Le-Conte" pear trees irrigated by bubbler irrigation system induced fruits had significantly the heaviest weight and the greatest size. Contrary to that, pear trees irrigated with surface irrigation system was the inferior whereas, the results in inducing significantly the lightest weight and the smallest size of pear fruits. Such trend was true during both 2011 and 2012 seasons of study.

C-1-2. Fruit firmness:

Concerning the response of fruit firmness to both investigated irrigation systems under study i.e., bubbler irrigation system and surface irrigation system, data presented in the same abovementioned Table (8) revealed obviously that the response followed a similar trend during both 2011 and 2012 seasons. However, the firmest fruits were resulted by surface irrigation system while, the opposite trend was observed with fruit produced from trees irrigated by bubbler system which induced the lowest value of fruit firmness. Moreover, differences between the two irrigation systems were relatively not so pronounced to be taken into consideration from the statistical standpoint during the first and second seasons of study.

Table (8): Fruit size (cm^3), fruit weight (g.) and fruit firmness ($lb/inch^2$) of "Le-Conte" pear trees in response to both surface irrigation system and bubbler irrigation system during both 2011 and 2012 seasons.

Irrigation system	Fruit size (cm^3)		Fruit weight (g.)		Fruit firmness ($lb/inch^2$)	
	2011	2012	2011	2012	2011	2012
Bubbler irrigation	170.0a	194.3a	170.2a	193.5a	15.30a	15.27a
Surface irrigation	121.0b	148.3b	120.9b	150.0b	15.87a	16.07a

C-1-3. Fruit polar and equatorial diameter:

Considering the effect of the tow investigated irrigation systems on both polar diameter and equatorial diameter (cm) of "Le-Conte" pear fruits. Data in Table (9) displayed obviously that, both studied fruit characters increased significantly by bubbler irrigation system as compared to those fruits resulted from another irrigation system (surface). Since, the greatest values of fruit polar diameter and fruit equatorial diameter were statistically in closed relationship with those trees irrigated with bubbler irrigation system meanwhile, the other irrigation system induced significantly the lowest values in this concern. Such trend was observed and true during the first and second seasons of study.

C-1-4. Fruit shape index:

It is quite evident from obtained data regarding the fruit shape index and tabulated in Table (9) that, variation due to the effect of both investigated irrigation systems under study i.e., bubbler irrigation system and surface irrigation system were so little and could be safely neglected whereas, the differences were so slight to reach level of significance. Such trend was true during the two seasons of study.

Table (9): Polar diameter (cm.), equatorial diameter (cm.) and fruit shape index, of "Le-Conte" pear trees in response to both surface irrigation system and bubbler irrigation system during both 2011 and 2012 seasons.

Irrigation system	Polar diameter (cm.)		Equatorial diameter (cm.)		Fruit shape index	
	2011	2012	2011	2012	2011	2012
Bubbler irrigation	7.45a	8.42a	6.33a	7.02a	1.18a	1.19a
Surface irrigation	6.61b	6.18b	5.80b	5.43b	1.14b	1.14b

Positive effects of transition from surface irrigation to bubbler irrigation system were identified on fruit quality. The results of this study support the conclusions of Landsberg and Jones (1981) and Bergamini *et al*., (1990) reported for Golden Delicious apple variety that fruit diameter increased as the irrigation amount in bubbler irrigation system increased. Cay *et al*., (2009) identified the highest fruit diameter in Kcp = 1.0 treatments for apple trees with bubbler irrigation system. Although fruit length values also increased up to a certain level (Kcp3 = 1.0). As excepted fruit diameter, length and fruit weight were lower in surface irrigation than bubbler irrigation treatments.

C-2. Fruit chemical properties:

C-2-1. Fruit juice total soluble solids:

Data represented in Table (10) displayed obviously that, two opposite trends were observed regarding the effect of both bubbler irrigation system and surface irrigation system on fruit juice total soluble solids during both 2011 and 2012 seasons of study. However, in the first season (2011) fruit juice TSS negatively responded the bubbler irrigation system.

On the other hand, in the second season (2012) fruit juice TSS was in positive relationship to bubbler irrigation system. Since, it exhibited statistically the highest value of TSS % than the other irrigation system (surface) which induced the least significant value in this respect.

C-2-2. Fruit juice total acidity:

Concerning the fruit juice total acidity %, data tabulated in the same Table (10) revealed clearly that, variations due to the effect of irrigation types were used in this study (bubbler and surface) were so little and could be safely neglected whereas, the differences were so little to reach level of significance. This trend was true during both 2011 and 2012 seasons of study.

C-2-3. Fruit TSS/acid ratio:

Tabulated data in the same aforesaid Table (10) showed clearly that, fruit juice TSS/acid ratio was responded to both irrigation systems (surface and bubbler systems) in the two seasons.

However, bubbler irrigation system was the superior method as exhibited the highest value of TSS/acid ratio meanwhile, surface irrigation system was the inferior between the two investigated irrigation systems were no significant as they were compared to each other.

Table (10): Total soluble solids (%), total acidity and TSS/acid ratio of "Le-Conte" pear trees in response to both surface irrigation system and bubbler irrigation system during both 2011 and 2012 seasons.

Irrigation system	TSS %		Acidity %		TSS/acid ratio	
	2011	2012	2011	2012	2011	2012
Bubbler irrigation	12.33a	14.67a	0.104a	0.149a	133.6a	99.03a
Surface irrigation	12.00a	13.50b	0.108a	0.161a	111.7a	87.56a

In general, total soluble solids values decreased as the amount of irrigation water increased. This results go parallel the findings of Drake *et al*., (1981) they reported that the total soluble solids content were higher for less irrigated fruits than excessively irrigated fruits. Surface irrigation treatment showed low soluble solids values for both years.

D- Leaf mineral composition (leaf macronutrients content):

Considering the leaf content of some macro elements, i.e., (N, P and K) of "Le-Conte" pear trees under the two irrigation system (surface and bubbler systems), data tabulated in Table (11) displayed obviously that variations due to the effect of irrigation systems under study were so light and could be safely neglected whereas, the differences were so little to reach level of significance. It could be noticed that, the absent of significance in the response of (N, P & K) leaf content to both surface irrigation system and bubbler irrigation system was detected during both the first and second seasons of study.

Table (11): Nitrogen, phosphorus and potassium (%)of "Le-Conte" pear trees in response to both surface irrigation system and bubbler irrigation system during both 2011 and 2012 seasons.

Irrigation system	Nitrogen (%)		Phosphorus %		Potassium (%)	
	2011	2012	2011	2012	2011	2012
Bubbler irrigation	2.033a	2.062a	0.250a	0.252a	1.243a	1.252a
Surface irrigation	2.017a	2.029a	0.253a	0.254a	1.240a	1.253a

The obtained results are in conformity with that previously mentioned by Kato and Narita (1989), Buwalda and Lenz (1992) on apple and Fathi (1999a) on pear mentioned that water stress reduced the leaf nitrogen content, while Ibrahim (2001) found that water logged citrus seedlings recorded the lowest nitrogen percentage than both normal and stressed seedlings.

Generally, it could be concluded that irrigation "Le-Conte" pear trees with bubbler irrigation system was the best and the most effective irrigation system as compared to another irrigation system (surface) for increasing tree productivity and improving fruit characteristics.

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دراسة مقارنة عن تأثير تغيير نظام الرى السطحى إلى نظام الرى بالببلر لأشجار الكمثرى الليكونت

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أجرى هذا البحث خلال عامين ٢٠١١ و٢٠١٢ بهدف تقييم تأثير تغيير نظام الرى من طريقة الرى بالغمر إلى نظام الرى بالببلر على بعض القياسات المائية وقياسات النمو الخضرى والجذور وكذلك قياسات الإثمار وجودة الثمار ومحتوى الأوراق من العناصر لأشجار بالغة من الكمثرى (ليكونت).

وقد أشارت النتائج المتحصل عليها إلى أن طريقة الرى بالغمر كانت أعلى استهلاكاً لماء الرى مقارنة لنظام الرى بالببلر حيث سجلت الأرقام ما يلى (٦٥٩٠، ٣٣١١ م³/فدان) فى الموسم الأول، وكذا (٦٣٩٨، ٣٣٠٨ م³/فدان) فى الموسم الثانى على التوالى. وكان الاستهلاك الشهرى منخفض خلال شهر فبراير ثم زاد الاستهلاك ليصل لأقصى حد خلال شهرى يونيو ويوليو ثم انخفض مرة أخرى.

كذلك أوضحت النتائج أن نظام الرى بالببلر أدى إلى زيادة معنوية فى قياسات النمو الخضرى ونمو الجذور مثل (طول النمو الخضرى – عدد الأوراق/نمو – مساحة الورقة – طول الجذور – عدد الجذور – الوزن الجاف للجذور).. والأكثر من ذلك فقد أدى نظام الرى بالببلر إلى زيادة معنوية أيضاً فى كل قياسات الإثمار التى تم دراستها (النسبة المئوية لعقد الثمار – عدد الثمار/شجرة – المحصول كجم/شجرة أو طن/فدان) .. هذا بالإضافة إلى أن معظم الصفات الطبيعية والكيماوية للثمار والتى تم دراستها قد تحسنت عن طريق نظام الرى بالببلر مقارنة بطريقة الرى بالغمر خلال موسمى الدراسة.

كما أظهرت النتائج المتحصل عليها أن محتوى الأوراق من العناصر (نتروجين – فوسفور – بوتاسيوم) لم تتأثر معنوياً بواسطة كلا من طريقتى الرى تحت البحث خلال موسمى ٢٠١١، ٢٠١٢ من الدراسة.

وخلاصة ذلك أنه يمكن القول والتوصية بصفة عامة أنه يمكن تغيير طريقة الرى بالغمر إلى نظام الرى بالببلر لأشجار الكمثرى البالغة والمنزرعة فى أراضى طمية مما يؤدى إلى توفير مياه الرى بالإضافة إلى الحصول على محصول عالى من الثمار ذو جودة عالية وكذلك الحصول على مجموع جذرى قوى مع أكبر معدل للاستفادة من الاستخدام الأمثل لمياه الرى.

قام بتحكيم البحث

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Table (4): Root length (cm.) of "Le-Conte" pear trees in response to both surface irrigation system and bubbler irrigation system during 2012 season.

Irrigation system (A)	Distances (B)	Roots less than 2 mm (root depths cm) (C)				Roots 2-6 mm (root depths cm) (C)				Roots > 6 mm (root depths cm) (C)			
		0-30	30-60	60-90	Average (A x B)	0-30	30-60	60-90	Average (A x B)	0-30	30-60	60-90	Average (A x B)
Bubbler	**100 cm**	964.1a	561.4b	588.2b	**704.6A**	39.33c	73.50a	59.27b	**57.37A**	60.00a	52.67ab	43.67b	**52.11A**
	200 cm	370.3d	356.8de	259.9f	**329.00B**	33.73cd	31.00c-e	29.00c-f	**31.24B**	20.50cd	9.67de	6.50e	**12.22BC**
Average (A x C)		**667.2A**	**459.1B**	**224.1B**	**516.8A**	**36.53BC**	**52.25A**	**44.13AB**	**44.31A**	**40.25A**	**31.17AB**	**25.08BC**	**32.17A**
Surface	**100 cm**	468.3c	316.0d-f	296.0ef	**360.1B**	36.00cd	25.00d-f	17.00f	**26.00BC**	27.00c	14.00c-e	8.00de	**16.33B**
	200 cm	185.2g	151.7g	140.0g	**159.0C**	26.00c-f	17.67ef	17.00f	**20.22C**	7.00e	5.00e	5.00e	**5.67C**
Average (A x C)		**326.8C**	**233.9D**	**218.0D**	**259.5B**	**31.00CD**	**21.33DE**	**17.00E**	**23.11B**	**17.00CD**	**9.50DE**	**6.5E**	**11.00B**
Average (B x C)	**100 cm**	**716.2a**	**438.7b**	**442.1b**	**532.3A**	**37.67b**	**49.25a**	**38.13b**	**41.68A**	**43.50a**	**33.33b**	**25.83b**	**34.22A**
	200 cm	**277.8c**	**254.3c**	**200.0d**	**244.0B**	**29.87bc**	**24.33c**	**23.00c**	**25.73B**	**13.75c**	**7.33c**	**5.75c**	**8.95B**
Average (C)		**497.0a**	**346.5b**	**321.0b**	**-**	**33.77A**	**36.79A**	**30.57A**	**-**	**28.63A**	**20.33B**	**15.79B**	**-**

Values having the same letter (s) within the same column are not statistically significant.

Table (5): Number roots of "Le-Conte" pear trees in response to both surface irrigation system and bubbler irrigation system during 2012 season.

Irrigation system (A)	Distances (B)	Roots less than 2 mm (root depths cm) (C)				Roots 2-6 mm (root depths cm) (C)				Roots > 6 mm (root depths cm) (C)			
		0-30	30-60	60-90	Average (A x B)	0-30	30-60	60-90	Average (A x B)	0-30	30-60	60-90	Average (A x B)
Bubbler	**100 cm**	799.7a	416.0b	380.0b	**531.9A**	5.00b	9.00a	8.7a	**7.56A**	5.33a	5.00ab	4.00a-c	**4.78A**
	200 cm	258.3c	237.0cd	163.0de	**219.4C**	5.00b	4.00bc	4.00bc	**4.33B**	2.00cd	1.33d	1.00d	**1.45C**
Average (A x C)		**529.0A**	**326.5B**	**271.5BC**	**375.7A**	**5.00AB**	**6.50A**	**6.33A**	**5.94A**	**3.67A**	**3.17A**	**2.50AB**	**3.11A**
Surface	**100 cm**	379.0b	287.0c	243.0cd	**303.0B**	4.00bc	5.00b	4.00bc	**4.33B**	3.00b-d	3.00b-d	2.00cd	**2.67B**
	200 cm	143.0e	112.0e	83.0e	**112.7D**	2.00c	3.00bc	3.00bc	**2.67C**	2.00cd	2.00cd	1.00d	**1.67BC**
Average (A x C)		**261.0C**	**199.5D**	**163.0D**	**207.8B**	**3.00C**	**4.00BC**	**3.50BC**	**3.50B**	**2.50AB**	**2.50AB**	**1.50B**	**2.17A**
Average (B x C)	**100 cm**	**589.3a**	**351.5b**	**311.5b**	**417.4A**	**4.50b**	**7.00a**	**6.33a**	**5.94A**	**4.17a**	**4.00a**	**3.00ab**	**3.72A**
	200 cm	**200.7c**	**174.5cd**	**123.0d**	**166.1B**	**3.50b**	**3.50b**	**3.50b**	**3.50B**	**2.00bc**	**1.67bc**	**1.00c**	**1.56B**
Average (C)		**395.0A**	**263.0B**	**217.3C**	**-**	**4.00B**	**5.25A**	**4.92AB**	**-**	**3.08A**	**2.83AB**	**2.00B**	**-**

Values having the same letter (s) within the same column are not statistically significant.

Table (6): Root dry weight (g.) of "Le-Conte" pear trees in response to both surface irrigation system and bubbler irrigation system during 2012 season.

Irrigation system (A)	Distances (B)	Roots less than 2 mm (root depths cm) (C)				Roots 2-6 mm (root depths cm) (C)				Roots > 6 mm (root depths cm) (C)			
		0-30	30-60	60-90	Ave. (A x B)	0-30	30-60	60-90	Ave. (A x B)	0-30	30-60	60-90	Ave. (A x B)
Bubbler	100 cm	3.14ab	2.82bc	2.65bc	**2.87A**	2.46c-e	3.22ab	3.28ab	**2.98A**	27.22bc	24.80b-d	57.77a	**36.60A**
	200 cm	2.63b-d	2.29c-e	1.92de	**2.28B**	2.43c-e	2.97a-c	2.26de	**2.55B**	9.82c-e	2.32e	1.17e	**4.44C**
Average (A x C)		**2.89AB**	**2.56BC**	**2.29C**	**2.58A**	**2.44C**	**3.10AB**	**2.77BC**	**2.77A**	**18.52AB**	**13.56B**	**29.47A**	**20.52A**
Surface	100 cm	3.60a	2.70bc	2.50b-d	**2.93A**	3.52a	2.97a-c	1.87ef	**2.79AB**	32.00b	17.00b-e	15.00b-e	**21.33B**
	200 cm	2.65bc	1.93de	1.76e	**2.11B**	3.00a-c	2.74b-d	1.50f	**2.41B**	7.00de	1.60e	1.30e	**3.30C**
Average (A x C)		**3.13A**	**2.32C**	**2.13C**	**2.52A**	**3.26A**	**2.86A-C**	**1.69D**	**2.60A**	**19.50AB**	**9.30B**	**8.15B**	**12.32AB**
Average (B x C)	**100 cm**	**3.37a**	**2.76b**	**2.58bc**	**2.90A**	**2.99ab**	**3.09a**	**2.57b**	**2.89A**	**29.61ab**	**20.90bc**	**36.38a**	**28.96A**
	200 cm	**2.64b**	**2.11cd**	**1.84d**	**2.20B**	**2.71ab**	**2.86**	**1.88C**	**2.48B**	**8.41cd**	**1.96d**	**1.24d**	**3.87B**
Average (C)		**3.01A**	**2.44B**	**2.21B**	**-**	**2.85A**	**2.98A**	**2.23B**	**-**	**19.01A**	**11.43A**	**18.81A**	**-**

Values having the same letter (s) within the same column are not statistically significant.