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Impact of applied irrigation regime during specified phenological stages on cropping and its' attributes of "Le-conte" pear

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Abstract

This study was carried out during three successive seasons 2013, 2014 and 2015 on seventeen years old Le-Conte pear trees. The first season was considered to be on preliminary season to eliminate the residual effects of the previously used irrigation treatments. Pear growing season was split to four phenological stages (stage I beginning of flowering to final fruit set, stage II from initial fruit set to final fruit set, stage III final fruit set to harvesting and stage IV harvesting to leaf shed). However, control trees received 100 % of crop water requirement during all stages while the remaining trees received three water regimes (60, 80 and 120% of crop water requirement) applied at each of the phonological stages and then irrigated with the stayed stages were receiving optimal level of irrigation requirement (100 %) for the remaining stages. The fruit set%, fruit abscission%, yield (Kg), fruit characteristic (fruit weight (gm.), fruit firmness, juice TSS % titratable acidity %), chemical analysis (Leaf content of macro nutrients (nitrogen, phosphorous, potassium content (%),magnesium, iron , zinc, manganese and copper contents (**mg/l**) and leaf content of photosynthetic pigments (chlorophyll (a,b) and carotenoids) parameters were assessed.

Results showed that enhancements of fruit set percentage were induced by applying 60% of the actual requirement during stage II, fruit abscission declined by increasing the applied water quantities during stage IV and producing significantly the highest yield per tree, fruit weight increase by increasing the applied water quantities during stage III, firmness and TSS increases with decreasing the actual requirement during any studied stages, the highest leaf nitrogen content was due to applying the highest regime during stage III, increasing potassium, phosphorus, magnesium, iron , copper and chlorophyll contents were attributed to the lowest regime when applied during stage II, leaf zinc and manganese content increased by applying the highest regime during stage II.

Key words: Le Conte pear- water regimes - fruit set - fruit abscission - fruit weight – firmness - . TSS – chlorophyll - nitrogen - phosphorus - potassium – iron - zinc – manganese - copper

Introduction

Pear is one of the most important fruits grown worldwide. It ranks the sixth concerning the cultivated area. "Le Conte" is the main pear cultivar in Egypt. It resulted as a hybrid between (Pyrus Communis, L.) and (Pyrus Serotina, Rehd). The cultivated area reached 9404 feddans which produced about 58852 tons with an average production of 6.26 tons/feddan (Ministry of Agriculture, 2013) while the world an average production of 7.94 tons/feddan (Fao stat,2013).

Flowering is generally considered a critical period for a large number of crops. Water restrictions during this phenological stage can inhibit ovule fertilization (Hsiao, 1993), reducing drastically the final number of fruit and consequently the yield. Water stress that develops during the spring or early summer can have dramatic effects on, fruit set and fruit growth, because early season shoot growth and early development of fruit are primarily by cell division processes. Water stress that develops during mid-summer, i.e., after canopy development and fruit set, will have less effect on vegetative growth and fruit yield. Late season processes such as flower bud development, root growth, and nutrient uptake, reserve storage and winter acclimatization are affected by late season water stress (Kuroda *et al.,* 1985).

On the other hand, the world faces very serious global warming, which will produce a general warming and significantly increase the evaporative demand and the irrigation requirement for crops. For this reason, irrigation efficiency is becoming increasingly important in arid and semi-arid regions with limited water resources. Therefore, it is necessary to adopt specialized and efficient methods of irrigation,. In order to achieve the twin objectives of higher productivity and optimum use of water (Gercek *et al.,* 2009).

One of the options proposed for a more efficient use of irrigation water is the application of regulated deficit irrigation (RDI) (Mitchell *et al.,* 1984), which is based on the restriction of water supplies during certain stages of crop development, when yield and fruit quality have low sensitivity to reduction in water, providing normal irrigation during the rest of the season, especially during the «critical periods» or phenological stages with a higher sensitivity to water deficit (Mitchell *et al.,* 1984; Chalmers *et al.,* 1986).

Effects of RDI on water savings, yield, water use efficiency (WUE) and quality in different crops and fruit trees have been widely reported since the 1980s (Dong *et al.,* 2006). RDI techniques have been successfully applied to many fruit trees such as peaches (Chalmers *et al.,* 1981), pears (Chalmers *et al.,* 1986; Mitchell *et al.,* 1986), Asian pears (Behboudian *et al.,* 1994) and grapefruits (Cohen and Goell, 1988).

Overall, the results on fruit trees showed that water deficits and the associated water stresses during developmental stages would not negatively affect fruit yield. Many researchers have reported effects of regulated water deficits on vegetative growth, flowering, fruit growth, and yield in different pear tree cultivars under different climatic conditions (Mitchell *et al.,* 1984, 1986; Caspari *et al.,* 1994; Marsal *et al.,* 2000). Some investigators found that RDI techniques used from the early stages of fruit growth up to the end of shoot growth affected vegetative growth by inhibiting shoot development, but did not affect the final fruit size, number of fruit produced or yield (Chalmers *et al*., 1984; Li *et al.,* 1989). Goldhamer *et al.* (2006) reported variations in the effects of water stress treatments applied at different times on the yield and yield components of almonds. RDI saved 25% of the summer irrigation water used in California but did not reduce the final yield in olive trees (Goldhamer, 1999). There was also no negative effect on loquat quality and yield with RDI treatments (Cuevas *et al.,* 2007).

Fruit quality is an important factor for its market value. Application of inappropriate amounts of irrigation at incorrect time is waste of water resources and can lead to poor fruit quality. Since the 1990s, the effects of RDI on fruit quality and related soil water deficit index have been studied using both qualitative descriptions and quantitative indices (Behboudian and Mills, 1997). Some investigators revealed that RDI could improve fruit quality in terms of physical and chemical attributes (Liu *et al.,* 2001; Verreynne *et al.,* 2001). Li (1993) reported that deficit irrigation during fruit development and post-harvest in peach trees significantly reduced vegetative growth, but fruit production was not affected until the fourth consecutive year. Deficit irrigation in grapevines not only saved irrigation water by 50%, but also increased the WUE greatly without any yield reduction and improved berry quality and taste (Dos Santos *et al.,* 2007). To obtain the maximal pear yield and optimal fruit quality, it is necessary to understand the growth phases of trees, especially the most susceptible phase to irrigation.

According to Le *et al.,* (1989) and Girona *et al.,* (1997), Timing of water deficits was found to have important effects on productivity of fruit trees. On the other hand, excessive water may have adverse effects on fruit quality, since it increases vegetative growth, promoting nutritional imbalance and decreasing fruit dry mass (Liao and Lin, 2001; Jackson and Colmer, 2005).

One of the benefits of RDI its' importance in maintaining the fruit taste and quality (Li *et al*., 1989; Mills *et al*., 1996; Mpelasoka *et al*., 2000). Soluble solids content (SSC) and titratable acidity (TA) warrant particular attention due to their importance in fruit taste (Crisosto *et al*., 1994).

The effect of irrigation level on leaf mineral content was reported by numerous researchers as Abd El-Nasser and El-Shazly, (2000) and Mikhael and Mady, (2007) on apple. They mentioned that, there is a general significant positive effect on the percent of N, P and K in leaves due to increasing available soil water. Similarly, Khalil, (2004) on olive found that, K content in leaves was significantly reduced by decreasing irrigation rate. Channel and Ranbirsingh (1992) on mango and Ahmed (1994) on pomegranate trees indicated that, leaf content of Ca was greater with increasing irrigation levels.

Photosynthetic pigments content in leaves was significantly higher in the "Canino" apricot and "Anna" apple trees grown under high irrigation rate (El- Seginy, 2006, Mikhael, and Mady, 2007). This increment in leaf pigment concentration could be attributed to increasing of macronutrient uptake, especially N and Mg as a consequence of improved soil moisture under irrigation (Khattab, *et al.*, 2011)

The main objective of the present investigation was to assess the impact of applied water regimes during specified phenological stages on yield and its' attributes , and the accompanying changes in leaf content of micro & macro nutrients photosynthetic pigments of "Le-Conte" pear trees.

Material and methods

Experimental conditions and plant material

The present experiment was performed during 2013, 2014 and 2015 in 2.5 feddans plot at a private orchard, located in in at El-Khatatba district, Minufiya governorate. Mature "Le-Conte" pear trees budded on *Pyrus communis* rootstock, spaced 5 × 5 m, vase trained and subjected to cultural practices recommended by the Ministry of agricultural, with an average height of 3.5 m, and ground cover of about 85% were adopted. Trees were drip irrigated using two drip irrigation lines for each row.

Soil physical and chemical properties were determined in the laboratory of the Soil, Water and Environmental Res. Inst. according to the methods described by Jackson (1973) and the results are summarizing in Table (1).

Table 1. Physical and chemical properties of the orchard soil.

	Parameter	Soil sample depth	
		0-30 cm	30-60 cm
		Value	
Physical properties	**Fine sand %**	40.43	39.28
	Coarse sand %	45.18	48.00
	Silt %	5.66	3.35
	Clay %	8.73	9.37
	Texture class	L. Sand	L. Sand
		loamy	
chemical properties	Ec (ds/m)	9.25	3.98
	Ca++ (me/l)	19.5	8.5
	Mg++	53.5	25.5
	Na+	16.4	3.5
	K+	0.96	0.56
	Co3--	-	-
	HCo3 -	5	4
	Cl-	74.5	29
	So4--	10.86	5.06
	PH	7.82	7.79
	Sp%	36.7	31.8

The experimental design of each irrigation treatment was 4 standard experimental plots distributed randomly in blocks. The standard plot was made up of 15 trees, organized in 4 adjacent rows. The 3 central trees of the middle row were devoted for assessments (each tree acting as a replicate, and the other 12 trees were guard trees.

Irrigation treatments:

The present research study was initiated in 2013and extended for three successive growing seasons. The first season was considered to be a preliminary season to eliminate the residual effects of the previously used irrigation treatments. Pear growing season was split to four phonological stages as presented in Table (2). However, control trees received 100 % of irrigation requirement during all stages while the remaining trees received three water regimes (60, 80 and 120% of irrigation requirement) applied at each of the phonological stages and then irrigated was applied for the remaining stages with 100% of the water requirements. After the last phonological stage, irrigation was withhold till the commencement of stage 1

Table 2. The adopted phonological stages

Phonological stage		Date	No. of days from beginning of flowering
stage I	beginning 10% flowering to final fruit set (six weeks after petal full) (F-I.FS)	07/03 to 15/4/2014-15	37 days
stage II	from initial fruit set (three weeks after petal full) to final fruit set (I.FS - F.FS)	15/04 to 7/05/2014	21 days
stage III	final fruit set to harvesting (F.FS- H)	7/05 to 15/08/2014	83 days
stage IV	harvesting to natural defoliation or leaf shed (H - D)	15/08 to 1/11/2014	75 days

The applied levels of irrigation were calculated as daily crop water requirements (liter/tree/day), as follow:

1 – The 1st irrigation level (optimum rate) = 100% of the crop water requirement (CWR), this amount of water was calculated theoretically from the "TAHRIR" meteorological data of the planting region.

2 - The 2nd irrigation level (high rate) = 120% of the CWR.

3 - The 3rd irrigation level (moderate rate) = 80% of the CWR.

4 - The 4th irrigation level (low rate) = 60% of the CWR.

The relative requirements were applied by changing the number and or discharge of emitters used. Water requirements were calculated as elucidated by Karmeli and Keller (1975):

IR = (Se.SL.ETo.Kc.Kr/Ea)*(1/1-Lr)

IR = Daily irrigation requirements

Se. SL	=	Plant area (Plant distance on lateral* between laterals)
ETo	=	Daily reference evapotranspiration on mm/day
Kc	=	coefficient factor for pear trees (Allen, *et al.,* 1998).
Kr	=	Reduction coefficient Gc/0.85
Gc	=	Ground cover (area of tree canopy)
Ea	=	Efficiency of irrigation system (80-90%)
Lr	=	Leaching requirements = Eci/Ecd
Eci	=	Electrical conductivity of irrigation water
Ecd	=	Electrical conductivity of drainage water

Whereas**,** The ETo value was calculated using the atmospheric conditions data prevailing at El-Khatatba district. Crop irrigation requirements were scheduled weekly according to daily ETo, Since, Penman Monteith method was used to calculate ET crop for pear trees in the district during 2014 and 2015 seasons of study using CROPWAT model (Smith 1991).

$$ETo = \frac{0.408\ \Delta(Rn - G) + \gamma\ [900/(T + 273]\ U2\ (es\text{-}ea)}{\Delta + \gamma\ (1 + 0.34\ U2)}$$

ETo	=	reference evapotranspiration, mm/day
Rn	=	net radiation (MJm-2d-1)
G	=	soil heat flux (MJm-2d-1)
Δ	=	slope vapor pressure and temperature curve (kPa °C-1)
Γ	=	psychrometric constant (kPa °C-1)
U2	=	wind speed at 2 m height (ms-1)
es-ea	=	vapor pressure deficit (kPa)
T	=	daily air temperature at 2 m height (°C)

Crop coefficient (KC) value was used for quantifying crop water use. It was calculated from the equation: KC = ETc / ETo; where ETc is ETe/ETo the actual water consumptive use and ETo is the reference (potential evapotranspiration).

The correction coefficient for ground cover was according to Fereres and Goldhmaer (1990).

To unify the applied nutrients, application was done manually on weekly basis

Assessments

1. Fruit Set %

For each considered tree four scaffold branches were chosen at each of the four directions and tagged. The branches were of similar diameter and spur load as much as possible. At full bloom the number of flowers born on each branch was counted and at the fruit set stage (three weeks after full bloom) the number of set (fruitlets) born on each branch were counted. The fruit set % was calculated by the following equation according to Westwood (1978)

Percentage of fruit set = Number of fruit set/ Total number of flowers*100. (On four

2. Fruit abscission%

at harvests i.e. when fruits reached the maturity stage as previously described by El-Azzouni et al., (1975), the number of retained fruits on each tagged branch was counted and the abscission % was calculated according to the following equation

Fruit abscission%: number of all harvested fruits / number of fruit set *100 (According to Westwood, 1978).

3. Yield

When fruits reached the maturity stage according to El-Azzouni *et al.*, (1975), the number of fruits born on each tree were counted and multiplied by the average fruit weight born on that specific tree taken from a representing sample of ten fruits.

4. Fruit characteristic

At maturity, a representing sample of ten fruits was harvested from each considered tree and the following were assessed:

Fruit weight (gm.) using a digital scale, fruit firmness (lb/inch2) using a pressure tester, juice TSS % using a hand refractometer, and juice titratable acidity% as malic acid, A.O.A.C (1990).

6. Chemical analysis

a. Leaf content of macro nutrients

From each of the replicates that were devoted for chemical analysis a representing sample of thirty leaves born on the current season growth was taken in mid-July of each season and the leaves were washed with tap water and oven dried at 60 °C. A 0.5 gram of the dried samples was digested using the H_2SO_4 and H_2O_2 as previously described by Cottenie (1980). The extract was used to determine the following minerals:

Nitrogen content (%) in the digested solution by the modified microkjeldahl method as described by Plummer (1971). Phosphorous content% determined calorimetrically according to the method of Jackson (1958). Potassium content (%) against a standard using flame-photometer (Piper, 1950). Calcium and magnesium contents (**mg/l**) by using Atomic Absorption Spectrophotometer, Pye Unican SP1900, According to Brandifeld and Spincer (1965).

b. Leaf content of photosynthetic pigments:

The method used for the quantitative determination of chlorophyll according to (Vernon and Selly, 1966) was adopted. One gram aliquot of fresh leaves was cut into small pieces. The pigments were extracted by grinding the cut tissue with suitable amount of glass powder in mortar using 100 ml of 80% aqueous acetone (v/v). The homogenate was transferred quantitatively to a Buchner filter with Whatman No. 1 filter paper. The filtrate was transferred quantitatively to 100 ml volumetric flask and made up to a total volume of 100 ml using 80% acetone.

The optical density of the plant extract was measured using spectrophotometer of two wave lengths (649 and 665 nm). These are positions in the spectrum where maximum absorption by chlorophyll (a) and (b) occurs. The concentrations of chlorophyll (a), (b) and total chlorophyll in leaf plant tissue were calculated using the equations mentioned by Vernon and Selly, (1966).

Mg chlorophyll (a) / g tissue = 11.63(A665) – 2.39(A649).

Mg chlorophyll (b) / g tissue = 20.11(A649) – 5.18(A665).

Mg chlorophyll (a + b) / g tissue = 6.45 (A665) +17.72(A649).

For carotenoids, the concentration was determined according to (Lichtentahler 1987) equation:

$Car = 1000 \times OD_{470} - 1.82\ C_a - 85.02\ C_b / 198 =$ mg/g fresh weight.

Statistical analysis:

Split plot design was adopted for the experimental design. The statistical analysis of the present data was carried out according to Snedecor and Chocran (1980). Averages were compared using. Least Significant Difference (LSD) test according to Duncan (1955) at probability of 0.5% using MSTAT program.

Results and Discussion

Fruit set and Abscission %

Compared with control and remaining treatments, it was found that applying 60% of the actual irrigation requirements during stage II was the most effective treatment in inducing significantly the highest fruit set percentage. On the contrary statistically the lowest fruit set percentage was dedicated to applying highest irrigation rate during stage I in both seasons and the application of the lowest rate during stage IV in the second season only (Table, 3).

As for the lowest significant percentage of fruit abscission it was achieved due to application of 120% of the actual water requirements during stage IV. Whereas application of 60% of the actual water requirements during stages IV & I for both studied seasons respectively, induced statistically the highest percentages for this parameter. (Table, 3).

Table 3. Effect of water regime on initial fruit set and abscission percentage.

		Initial fruit set (%)		**Fruit abscission (%)**	
% of actual requirements	Phenological stages	2014	2015	2014	2015
Control 100%	during all stages	5.99	7.56	53.78	81.26
120%	stage I (F-I.FS)	3.88	5.35	51.92	78.59
	stage II (I.FS - F.FS)	5.61	12.16	72.31	83.80
	stage III (F.FS- H)	4.91	6.58	55.84	85.74
	stage IV (H - D)	5.57	8.84	35.42	68.68
80%	stage I (F-I.FS)	5.96	13.39	62.97	91.91
	stage II (I.FS - F.FS)	5.48	7.21	75.51	87.75
	stage III (F.FS- H)	5.92	11.78	58.97	84.33
	stage IV (H - D)	5.75	6.37	72.73	82.74
60%	stage I (F-I.FS)	5.31	13.96	39.66	95.24
	stage II (I.FS - F.FS)	7.14	15.72	67.36	77.15
	stage III (F.FS- H)	5.71	10.71	52.87	92.82
	stage IV (H - D)	4.20	5.12	76.33	92.81
LSD at 0.05		0.13	0.79	0.45	0.80

Previous reports by Nikbakht, *et al.,* (2011) on olive, Khattab,et al., (2011) on pomegranate and Eid et al., (2013) on apricots illustrated drastic decreases in fruit set due to water stress. Earlier reports by Hsiao, (1993) clarified that the effect of water stress on crop reduction is due to inhibition of ovule fertilization.

In addition, results illustrated that applying 60% of the actual irrigation requirements during stage II inducing significantly the highest fruit set. This finding was noticed to be accompanied by mark able increases in potassium, phosphorus and magnesium as shown in tables (7,8).

Potassium aids in building and moving carbohydrates from leaves to fruits and encouraging the biosynthesis of cellulose which positively strengthens the cell walls (Manjula Nathan, 2009). Phosphorus aids in forming phospholipids (Greamer and Bostock, 1986) and assists in enzyme activation and photosynthesis (Manjula Nathan, 2009). Mg is necessary for chlorophyll synthesis (Mengal and Kirkby, 1982) Thereby increases in the leaf content of those macro-nutrients might be the cause of increasing and or decreasing abscission.

Application of 60% of the actual water requirements during stages IV & I for both seasons respectively induced statistically the highest abscission percentages

This results are in agrement with George and Nissen، (1988); on apple and García-Tejero *et al.*, (2010) on citrus and Khattab, *et al*., (2011) on pomegranate.

Abscission is an active physiological process that occurs through the dissolution of cell walls at predetermined positions، the abscission zones, often is related to stress and senescence (Taylor and Whitelaw، 2001).Also, under water deficit causes loss of calcium and pectin from the wall of separation layer cells presumably leading to the dissolution of the pectin-rich middle lamella, weakening the cell wall and leading to disintegration of abscission zones tissues (Addicott, 1982; Tripathi *et al.,* 2008).

Moreover, water stress causes closure of stomata inducing lower photosynthetic (Kramer, 1995). This leads to decreasing the net resulting assimilates, Thereby increasing competition between developing fruitlets ended by higher abscission.

Yield and its' attributes

Results in table (4) illustrates that, increasing the rates applied to 120% of actual water requirements during (stage IV) in both seasons produced significantly the highest yield per tree. Whereas, the lowest yield was dedicated to reducing the applied water regime to 60% of actual water requirements during stages IV in both seasons of the investigation respectively.

In this respect, Küçükyumuk *et al.* (2013) on apples, Khattab *et al.* (2011) on pomegranate, Eid *et al*., (2013) on apricot attained results of similar trends.

Moderate water stress was found to improve the completion of flower bud development، resulting in higher flower intensity and fruit set in subsequent seasons (Mitchell *et al.,* 1989). While, severe postharvest water stress decreased the productivity in the subsequent year (Torrecillas *et al.,* 2000; Naor *et al.,* 2005), this was due to reduced flowering intensity (Girona *et al.,* 2003) and lower fruit set (Ruiz-Sanchez *et al.,* 1999; Torrecillas *et al.,* 2000; Girona *et al.,* 2003). The lower fruit set was attributed to reduced pollen vitality (Ruiz-Sanchez *et al.* 1999), and delayed flower bud development (Naor *et al.,* 2005).

Physical attributes:

With respect to the average fruit weight, it amounted to statically its' highest magnitude when using the regime of 120% of the actual irrigation requirements during stage III in both seasons. On the contrary statistically the highest negative effect was due to applying the lowest rate during stages III &I for both seasons respectively (table 4).

Table 4. Effect of water regime on yield/tree and average fruit weight.

		yield/tree (kg)		**fruit Weight** (gm)	
% of actual requirements	Phenological stages	2014	2015	2014	2015
Control 100%	during all stages	113	35.67	234	251
120%	stage I (F-I.FS)	116	46.67	267	278
	stage II (I.FS - F.FS)	140	69.33	225	249
	stage III (F.FS- H)	171	78.67	273	333.
	stage IV (H - D)	186	127.83	257	275
80%	stage I (F-I.FS)	138	29.67	224	200
	stage II (I.FS - F.FS)	113	55.33	230	213.
	stage III (F.FS- H)	138	51.50	210	277
	stage IV (H - D)	146	36.33	212	242
60%	stage I (F-I.FS)	97	28.33	267	177
	stage II (I.FS - F.FS)	125	98.67	256	264
	stage III (F.FS- H)	157	46.00	176	258
	stage IV (H - D)	62	24.17	229	183
LSD at 0.05		1.14	1.79	1.13	0.80

These results are in agreement with Abd El-Messeih and Gendy (2009) on "Le-Conte" pear and Küçükyumuk et al. (2013) on apple.

These results might have been induced due to negative effects exerted by deficit water on reproductive cell division stage which lasts 30–40 days after full bloom (Westwood, 1993) leading to smaller fruits ending to lower yield and vice versa.

Data in Table (5) cleared that statistically the firmest fruits were dedicated to applying 80% of the irrigation requirements stage I in both seasons**.** On the contrary, significantly the least fruit firmness was attained by using highest irrigation dose (120%) during stage (I) in both seasons.

These results are in harmony with Ali (2006) on peach, Kandil and El-Feky (2006) on apricot and Mikhael and Mady (2007) and Küçükyumuk *et al.* (2013) on apple fruit.

The increase in fruit firmness of stressed trees could be an artifact of fruit size decreases as a direct impact of irrigation deficit. The firmness of apples was found to increase with decrease in fruit weight (Ebel *et al.* 1993)

Chemical attributes

Table 5. Effect of water regime on average fruit firmness, TSS and fruit acidity.

		fruit firmness (lb/inch2)		**TSS**		**juice acidity**	
% of actual requirements	Phenological stages	2014	2015	2014	2015	2014	2015
Control 100%	during all stages	16.22	19.83	13.17	12.33	0.015	0.019
120%	stage I (F-I.FS)	14.51	18.49	13.33	12.33	0.013	0.021
	stage II (I.FS - F.FS)	15.82	20.51	13.5	13.00	0.012	0.015
	stage III (F.FS- H)	15.72	19.75	12.33	11.67	0.013	0.015
	stage IV (H - D)	15.47	19.42	13.33	12.67	0.012	0.016
80%	stage I (F-I.FS)	16.97	21.38	13.67	12.00	0.013	0.019
	stage II (I.FS - F.FS)	15.59	19.90	13.33	13.33	0.016	0.021
	stage III (F.FS- H)	16.21	19.90	13.83	13.00	0.011	0.017
	stage IV (H - D)	15.05	20.28	14.01	12.40	0.015	0.016
60%	stage I (F-I.FS)	15.67	20.9	13.33	13.33	0.016	0.018
	stage II (I.FS - F.FS)	15.59	19.65	14.17	14.33	0.017	0.018
	stage III (F.FS- H)	16.51	20.40	12.83	13.33	0.015	0.017
	stage IV (H - D)	16.24	19.42	12.83	12.50	0.012	0.019
LSD at 0.05		0.13	0.15	0.1	0.8	0.005	0.007

Application of 60% from actual water requirements during stage I in both seasons was the most effective in inducing statistically the highest TSS%. On the contrary, significantly the lowest TSS% was dedicated to the application of 120% during stage III in both seasons (table 5).

In general, Ali et al. [1998] on apple, Hussein [2004] on pear and Abd El-Samad [2005] on guava achieved comparable findings in this concern.

Higher accumulation of sugars in early water stressed fruits was clarified by Kramer, (1983) to be as a result of enhancement of starch to sugar conversion due to this stress. Also our findings declared higher levels of both K &P due to water stress at stage II both are known to play pivotal roles in enhancing TSS formation (Jivan and Sala, 2014)

The results in table (5) showed that applied water regimes did alter the juice acidity in both of the considered seasons.

On the contrary, findings achieved by both Lawand and Patil (1996) and Shailendra and Agrawal (2005) on pomegranate declared significant effects of applied water regimes on juice acidity

Photosynthetic pigments

In general, the highest statistical leaf content of photosynthetic pigments was attributed to the lowest regime(60%) when applied during stage II. This was untrue for chlorophyll b content in the second season for the utmost statistically effective regime was 80% of the requirements during stage III. The 60% application during stage II ranked the second with significant differences. Whereas, significantly the lowest leaf contents were dedicated to the application of the highest regime during stage III in both seasons (table 6)

Table 6. Effect of water regime on leaf Chlorophyll a,b and carotenoids content.

		Chl. a		**Chl. b**		**Carotenoids**	
% of actual requirements	Phenological stages	2014	2015	2014	2015	2014	2015
100%	during all stages	3.63	2.30	2.19	1.15	5.24	3.16
	stage I (F-I.FS)	3.03	2.09	2.01	1.23	4.45	3.25
	stage II (I.FS - F.FS)	4.13	2.05	2.29	1.32	5.95	2.83
	stage III (F.FS- H)	2.28	1.55	1.68	1.07	3.65	1.87
120%	stage IV (H - D)	3.31	2.32	2.02	1.15	4.38	2.69
	stage I (F-I.FS)	3.07	1.95	1.97	2.24	4.33	2.92
	stage II (I.FS - F.FS)	2.63	2.45	1.9	1.72	3.75	2.21
	stage III (F.FS- H)	5.37	2.09	3.41	1.66	6.16	3.83
80%	stage IV (H - D)	5.61	2.13	2.15	1.55	6.26	3.32
	stage I (F-I.FS)	3.97	2.72	1.75	2.16	5.64	4.54
	stage II (I.FS - F.FS)	5.17	2.78	2.94	2.43	6.67	4.94
	stage III (F.FS- H)	4.51	2.30	1.88	1.87	5.39	3.16
60%	stage IV (H - D)	3.69	2.55	1.67	1.83	4.7	2.86
LSD at 0.05		0.57	0.09	0.26	0.08	0.57	0.79

Mensha *et al.* (2006) found that drought stress caused leaf chlorophyll to increase. Contradicting results were found by Pirzad *et al*., (2011) as they declared no differences in chlorophyll a, b due to in irrigation, at 100 and 55% field capacity.

Statistically the highest leaf content of photosynthetic pigments was attributed to the lowest regime when applied during stage II. This result may be due to associated increases in leaf, magnesium, which is necessary for chlorophyll synthesis, (Mengal and Kirkby, 1982).

b. Leaf mineral content

Statistically the highest leaf nitrogen content was due to applying the highest regime during stage III in both seasons. Whereas applying the same irrigation regime during stage I in both seasons induced significantly the lowest nitrogen content (table 7)

Table 7. Effect of water regime on leaf nitrogen and phosphorus content.

		Nitrogen %		**Phosphorus %**	
% of actual requirements	Phenological stages	2014	2015	2014	2015
Control 100%	during all stages	1.58	2.38	0.17	0.33
120%	stage I (F-I.FS)	1.33	1.36	0.14	0.28
	stage II (I.FS - F.FS)	1.67	2.76	0.17	0.30
	stage III (F.FS- H)	1.76	3.14	0.16	0.31
	stage IV (H - D)	1.70	2.75	0.16	0.33
80%	stage I (F-I.FS)	1.52	2.44	0.21	0.31
	stage II (I.FS - F.FS)	1.49	2.50	0.21	0.32
	stage III (F.FS- H)	1.55	2.40	0.20	0.34
	stage IV (H - D)	1.60	2.75	0.22	0.45
60%	stage I (F-I.FS)	1.40	1.52	0.25	0.45
	stage II (I.FS - F.FS)	1.49	1.75	0.30	0.50
	stage III (F.FS- H)	1.42	1.89	0.25	0.46
	stage IV (H - D)	1.55	2.26	0.26	0.43
LSD at 0.05 (season 2014) is		0.05	0.11	0.03	0.09

Phosphorus content was statistically at its' highest magnitude when trees were subjected to the lowest irrigation regime during stage II. Increasing the applied water quantities to 120% of the actual requirements during stage I resulted in the least content in both seasons. Statistically equal contents in the second season were dedicated to applying same quantities during the remaining stages, applying 80% during stages I, II and III (table 7)

Data in Table (8) clear that lowest irrigation regime (60%) added during stage II significantly induced highest leaf potassium content. Increasing the applied water quantities to 80 or 120% of the requirements during stage I resulted in significantly the lowest contents in both seasons. However these parameters were decreased by increasing the amount of water applied for the same stage to reach it utmost with the 120% application at same

Table 8. Effect of water regime on leaf potassium and magnesium content.

		Potassium %		**Magnesium** %	
% of actual requirements	Phonological stages	2014	2015	2014	2015
Control 100%	during all stages	**1.59**	**1.25**	0.**23**	**0.488**
120%	stage I (F-I.FS)	1.21	0.98	0.16	0.407
	stage II (I.FS - F.FS)	1.40	1.09	0.24	0.492
	stage III (F.FS- H)	1.35	1.50	0.17	0.499
	stage IV (H - D)	1.30	1.43	0.27	0.497
80%	stage I (F-I.FS)	1.21	1.03	0.21	0.459
	stage II (I.FS - F.FS)	1.40	1.09	0.28	0.480
	stage III (F.FS- H)	1.35	1.50	0.27	0.513
	stage IV (H - D)	1.30	1.43	0.25	0.514
60%	stage I (F-I.FS)	1.80	1.65	0.22	0.523
	stage II (I.FS - F.FS)	1.79	1.89	0.30	0.537
	stage III (F.FS- H)	1.60	1.58	0.29	0.518
	stage IV (H - D)	1.60	1.50	0.25	0.510
LSD at 0.05 (season 2014) is		0.18	0.06	0.009	0.013

Applying the lowest irrigation regime during stage II in both seasons induced significantly the highest leaf magnesium content. Whereas, the high water regime application during stage I in both season induced significantly the lowest content. (Table 8).

Statistically the highest leaf zinc content was due to applying the high regime during stage II in both seasons. Reducing the applied water to the low regime during stage IV in both seasons induced significantly the lowest zinc content (table 9).

Irrigation with 60% from actual water requirements in both seasons during stage IV, induced statistically the lowest leaf manganese content. Whereas, significantly the highest leaf manganese content was attributed to applying 120% of the requirements during stage II in the first season and continuous application of 100% of the requirements during all stages (control) in the second season (table 9).

Table 9. Effect of water regime on leaf zinc and manganese content.

		Zinc mg/l		**Manganese mg/l**	
% of actual requirements	Phonological stages	2014	2015	2014	2015
Control 100%	during all stages	37	13.00	133	**32.00**
120%	stage I (F-I.FS)	33	12.79	130	21.10
	stage II (I.FS - F.FS)	42	14.34	160	30.00
	stage III (F.FS- H)	41	13.87	135	21.00
	stage IV (H - D)	41	13.12	151	21.50
80%	stage I (F-I.FS)	37	12.98	155	19.40
	stage II (I.FS - F.FS)	36	12.71	125	19.76
	stage III (F.FS- H)	35	12 .67	122	19.50
	stage IV (H - D)	37	12.55	130	28.00
60%	stage I (F-I.FS)	33	12.00	131	25.18
	stage II (I.FS - F.FS)	36	12.24	150	21.71
	stage III (F.FS- H)	34	12.56	149	21.77
	stage IV (H - D)	32	11.08	119	18.92
LSD at 0.05 (season 2014) is		0.99	0.12	1.89	1.47

With respect to leaf contents of iron and copper it was at statistically the highest magnitude when trees were irrigated with 60% of the requirements during stage II in both seasons. Whereas, increasing the applied quantities to 120% y during stage I in both season led to statistically the least contents of those nutrients significant that negatively affect (table 10).

Table 10. Effect of water regime on leaf iron and copper content.

		Iron mg/l		**Copper mg/l**	
% of actual requirements	Phenological stages	2014	2015	2014	2015
Control 100%	during all stages	176.00	62.00	28.00	29.00
120%	stage I (F-I.FS)	169.00	56.00	23.00	20.60
	stage II (I.FS - F.FS)	172.00	58.00	25.00	28.00
	stage III (F.FS- H)	171.70	58.10	25.00	27.00
	stage IV (H - D)	176.00	60.10	27.00	29.00
80%	stage I (F-I.FS)	173.00	60.30	31.00	31.02
	stage II (I.FS - F.FS)	181.00	67.00	30.00	30.10
	stage III (F.FS- H)	180.00	63.00	28.00	29.10
	stage IV (H - D)	181.00	63.50	31.50	31.00
60%	stage I (F-I.FS)	188.67	68.01	33.00	32.10
	stage II (I.FS - F.FS)	190.00	195.10	35.00	37.60
	stage III (F.FS- H)	188.00	76.00	33.00	35.30
	stage IV (H - D)	179.00	66.90	29.00	26.80
LSD at 0.05 (season 2014) is		1.25	1.40	1.02	1.30

Variations in nutrients contents due to various regimes could be due to effect of various degrees of flooding on nutrient (Kozlowski and Pallardy, 1984), and also due to the effect of water /air ratio on nutrient absorption (Gil *et al*., 2012).

Conclusion

Various responses were attained when applying different regimes (percentages of water requirements) during specified phonological stages when compared with the continuous application of actual requirements. Positive effects on fruit set percentage and juice TSS% were achieved by the application of 60% of the actual requirements during stage II which might be attributed to higher contents of leaf magnesium, iron and phosphorous this was achieved due to better absorption which might be resulting from better water /air ratio. These nutrients contribute in the synthesis of photosynthetic pigments which were evident to increase in the leaves of the stressed trees. This would lead to higher photosynthetic activity leading to the manufacture of more assimilates. There by increasing the portion for each blossom leading to an increase in fruit set. Also increase in manufactured assimilates might be the cause of increasing the juice TSS%.

Also increases in fruit size went in parallel with high water supply in stage three this might be because water is essential for this developmental stage for optimal cell enlargement.

Finally further modeling studies are required to achieve highest returns for least water supplies

Altering the applied water regime to 120% of the actual requirements during stage IV induced significantly the highest yield and lowest abscission percentage. These findings might be justified that at this stage floral bud differentiation exists and that adequate water supply would increase both flowering density and quality. On the contrary statistically the highest negative effect was due to applying the highest rate during stages I for both seasons this result was obtained due to decreased potassium, phosphorus magnesium and nitrogen. Also, the seam negative effect by applying the lowest rate during stages IV this result was due to decreased zinc and manganese.

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تأثير مستويات الري خلال المراحل الفينولوجية المختلفة على المحصول وخصائصه للكمثرى الليكونت

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أجريت التجارب الحقلية فى هذه الدراسة بمزرعة خاصة بمنطقة الخطاطبة التابعة لمحافظة المنوفية خلال ثلاث مواسم ٢٠١٣ و ٢٠١٤و ٢٠١٥. وكان الموسم الاول للدراسة ٢٠١٣ هو دراسة تمهيدية للمواسم التالية واشتملت الدراسة على ثلاث مستويات لرى (١٢٠% و ٨٠% و ٦٠%) بالاضافة الى الاحتياج المائى ١٠٠% خلال اربع مراحل فينولوجية مختلفة وهى المرحلة الاولى وهى من بداية التزهير الى العقد النهائى والمرحلة الثانية وهى من العقد المبدئى الى العقد النهائى والمرحلة الثالثة وهى من العقد النهائى الى جمع المحصول ثم المرحلة الرابعة وهى من جمع المحصول الى بداية تساقط الاوراق وكانت الاشجار تحت المستوى المائى لتجربة ثم باقى المراحل الاخرى تحت المستوى المائى الامثل (١٠٠%) بالاضافة الى اشجار المقارنة (١٠٠% فى الاربع مراحل).

كانت القياسات المؤخوذة : نسبة العقد و نسبة التساقط والمحصول والصفات الثمرية (وزن الثمرة والصلابة ونسبة المواد الصلبة الذائبة والحموضة) والقياسات الكيميائية محتوى الاوراق من العناصر الغذائية (النيتروجين والفوسفور والبوتاسيوم والماغنسيوم والحديد والزنك والمنجنيز والنحاس) ومحتوى الاوراق من الكلورفيل أ وب والكاروتينات).

اظهرت نتائج الدراسة زيادة نسبة العقد عند المستوى المائى ٦٠% خلال المرحلة الثانية وانخفاض نسبة التساقط وزيادة المحصول بزيادة الاحتياج المائى بعد الجمع (المرحلة الرابعة) وكان افضل حجم الثمار عند ١٢٠% من الاحتياجات المائية اثناء المرحلة الثالثة وكانت اعلى نسبة صلابة ونسبة المواد الصلبة الذائبة بالثمار بتقليل الاحتياجات المائية فى اى مرحلة وكان اعلى محتوى للاوراق من النيتروجين عند اعلى مستوى مائى خلال المرحلة الثالثة بينما الفوسفور والبوتاسيوم والمغنسيوم والحديد والنحاس والكلورفيل عند اقل الاحتياجات المائية خلال المرحلة الثانية وكان اعلى محتوى لزنك والمنجنيز بزياة الاحتياج المائى خلال المرحلة الثانية.

الكلمات الدالة: الكمثرى الليكونت – المستوى المائى – : نسبة العقد – نسبة التساقط – المحصول –وزن الثمرة – الصلابة – نسبة المواد الصلبة الذائبة – الحموضة – النيتروجين – الفوسفور – البوتاسيوم – الماغنسيوم – الحديد –– الزنك– المنجنيز والنحاس– الكلورفيل أ وب – الكاروتينات