Plant Archives Vol. 20 Supplement 1, 2020 pp. 3304-3410 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

MODERATE DEFICIT IRRIGATION STRATEGY FOR IMPROVING WATER USE EFFICIENCY AND PRODUCTIVITY OF "KEITT" MANGO TREES

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Abstract

Water scarcity consider one of the main environmental constraints for plant growth and production under arid and semi-arid regions. Moderate water stress can constrain excessive vegetative growth in mango trees and stimulate flowering and productivity of mango. The current research was aimed to study the effect of three regular deficit irrigation levels *i.e.*, 100% IR (irrigation requirements), 85% IR, 70% IR of irrigation requirements on vegetative growth and productivity of "Keitt" mango trees during two seasons. Results indicated that, growing "Keitt" mango *cv.* under 100% IR enhanced vegetative growth (leaves number, leaf area, shoot diameter) however it increased malformation and powdery mildew infections. Moreover, trees irrigated with 100% IR recorded the highest relative water content (RWC), leaf water content (LWC) and decreased proline content. Sever deficit irrigation (70%) decreased significantly percentage of malformed panicles and powdery mildew infections. Moderate regular deficit irrigation (85% IR) increased initial fruit set, fruit number, yield, water use efficiency and relative water content compared to 70% IR. Different irrigation levels had no effect on fruit weight, volume, fruit acidity and vitamin C content. These results suggest that, moderate deficit irrigation (85% IR) bringing higher sustainable returns through control tree growth and increase productivity of "Keitt" mango trees.

Key words: yield, sunburn, powdery mildew, malformation, quality.

Introduction

Mango (*Mangifera indica* L.), consider an important member of Anacardiaceae family. World production around 50 million tons in 2017 (FAOSTAT, 2019). 'Keitt' mango trees are cultivated in the desert orchard of Egypt under sever heat stress and water shortage. For long season of fruit growth (6 months) it needs to more irrigation requirements.

Human faces a major challenge in meeting the continuous increase of water demands for population number and their needs under climatic changes with almost fixed amount of water resources. Arid and semiarid regions had a low and erratic rainfall, so irrigation is the common practiced. The main goal and challenge of recent agriculture is how to conserve water without any detrimental effect on yield and fruit quality.

Deficit irrigation water is one of the most appropriate strategy for solving water shortage. Their effects depending on the stage of plant growth. For instance, "Tommy Atkins" mango trees subjected to reduction in irrigation level at flower induction stage results in decreasing photosynthesis, transpiration and leaf water potential (Faria *et al.*, 2016). Also, water deficit during flowering and fruit set reduced mango fruit growth and size (Simmons *et al.*, 1995). Moreover, preharvest water shortage reduced mango fruit weight (Bithell *et al.*, 2010) and numbers (Lechaudel and Joas, 2007). On the other hand, water shortage at pre-flowering stage improved their flowering and fruit yield (Faria *et al.*, 2016). In South Africa, regular deficit water didn't affect significantly fruit weight, number and yield compared to progressive deficit water irrigation (Mthembu, 2001). Furthermore, in China, irrigation of "Guifei" mango trees at 65%-70% of field capacity recorded the highest water use efficiency and fruit yield compared to 79%-82%, 75%-78%, 71%-74% and 63%-66 (Wei *et al.*, 2017). Also, maximum yield of "Samar Bahisht Chaunsa" mango trees achieved by 14 days intervals followed by 7 days (Nasir and Mian, 1993). Moreover, Da Silva *et al*., 2009 irrigated Tommy

Atkins mango *cv*. at 90% IR increased water use efficiency and yield than irrigation at 70% of IR. Water stress delay the development of vegetative buds and stimulate the growth of floral buds (Sarker and Rahim, 2013).

Excessive irradiance for long periods of can cause water deficits due to reduce net CO_2 assimilation, the light-use efficiency, water-use efficiency, which restricts plant growthand yield (Goldschmidt, 1999). In an arid to semi-arid region where water deficit is considered to be the main environmental factor constraints tree growth and productivity (Boyer, 1982). Conversely, information regarding the effect of regular deficit irrigation on growth, production and fruit quality of "Keitt" mango trees under arid and semiarid region is rare. So, the aim of this study is evaluation of deficit irrigation water on growth, production and water use efficiency of "Keitt" mango trees

Material and Methods

Experimental conditions

This experiment was performed during two growing seasons (2016-2017 and 2017-2018) on eight years-old "Keitt" mango (*Mangifera indica* L.) trees, grown on Sukkary rootstock. Trees were placed at 2.5×4m in sandy soil located at El Behera Governorate, Egypt (30°41'42"N and 30°23'16" E, elevation 9 m). Trees were subjected to the common horticultural practices and received three irrigation requirement levels; 100%IR, 85% IR and 70% IR. Each treatment consisted of three replicates, each one contain 3 trees with.

Irrigation requirements (IR) were calculated according to (Allen *et al.,* 1998; Abdrabbo *et al*., 2013).

IR = Kc*ETo*LF*IE*R* Area (Feddan) / 1000

Where:

IR= Irrigation requirement (m3/fedan).

Kc= Crop coefficient (dimensionless).

ETo= Reference crop evapotranspiration (mm/day).

LF = Leaching fraction (assumed20% of irrigation water).

IE = Irrigation efficiency of the irrigation system in the field, (assumed 85% of the total applied).

R = Reduction factor (60% cover in this study)

Area = the irrigated area (one fedan = 4200 m2).

1000 = To convert from liter to cubic meter.

Water use efficiency was calculated according to FAO (1982).

WUE = Yield(kg) / IR(m^3)

Experimental design and irrigation treatments

Irrigation treatments were started at the beginning of November 2016 to November 2018. Tree received 12.5m^3, 10.62m^3 and 8.75 m^3/tree/year with 57 mm annual rainfall for 100%, 85% and 70% IR, respectively. Drip irrigation was located in a double line parallel to the tree row with the disposal of 4, 6 liters.

Twenty random branches were selected from each tree for determine the studied measurements (total 60 brunches for each treatment). Flowering measurements which include date of full bloom were determined (Julian date). Also fruiting measurements include initial and final fruit set were determined (when all flowers abscised but remained attached with the panicle) as number of fruits per panicle two weeks after petal fall and at harvest, respectively. Powdery mildew, malformation infection % and panicle branch numbers were determined. At harvest time fruit retention percent was determined using the following equation: Final fruit set/ Initial fruit set X 100. At maturity stage, number of fruits per tree was counted and yield (kg/tree). During October, leaf area (cm^2) and leaf number were determined Shoot length (cm) and diameter (mm) were determined. After harvest fruit weight (gm), volume (cm^3), length (cm), diameter (cm), peel weight (gm), pulp weight (gm) and seed weight (gm) were determined. Total sugars were determined according to Miller, 1958. Fruit TSS (%), titratable acidity (%) and vitamin "C" content (mg/100g Juice) were determined in mango fruit juice according to (A.O.A.C. 1990).

Physiological parameters include chlorophyll concentrations were color-metrically determined using Minolta SPAD-502. Leaf proline content (µmoles/g) was determined using the ninhydrin reaction according to the method of Bates *et al.*, (1973). Relative water content (RWC) and the leaf water content (LWC): Leaves were taken from mature leaves (the fourth distal adult leaf). The leaves were weighed, soaked in water for 45 minutes and dried at 70°C for 24 hours then RWC had been calculated according to Nomier, (1994).

$$RWC = [(FW - DW) / (TW - DW)] \times 100$$

Leaf water content (LWC%) had been calculated according to (Barrs, 1968) as the follow

$$LWC = [(FW - DW) / (DW)] \times 100$$

Where, FW= fresh weight; DW=dry weight; TW= turgid weight after immersion in distilled water for 24hour.

Water use efficiency was determined as follows:

Water use efficiency (kg/m^3) was calculated according to FAO, (1982) as follows:

WUE = Y(kg) / WR(m^3)

Where, Y- Yield and WR- Water requirements

Statistical analysis

A randomized complete block design with one factor was used for analysis all data with three replications for each parameter. The treatment means were compared by least significant difference (L.S.D.) test as given by Snedecor and Cochran, (1994) by used Assistat program

Results and Discussion

Vegetative growth

Data in table 2, show the effect of different regular deficit irrigation water on vegetative growth of "Keitt" mango trees. It was observed that, severe (70% IR) deficit irrigation decreased leaf area and shoot diameter. While, moderate deficit irrigation level (85% IR) increased leaves number per shoot and leaf area. It can be concluded that under deficit irrigation conditions mango trees tended to decreased leaf area than decreasing leaves number and tended to decrease shoot diameter than shoot length which may be a mechanism to alleviate drought stress.

These results go in line with Hsiao and Xu, (2000) who reported that, the reduction in mango leaf elongation exposed to water stress was more obvious, likely because of dehydration which resulted in reduced turgor, membrane extensibility of the leaf cells. Reducing leaf growth may be a survival mechanism for the plants to avoid tissue hydration by reducing transpiration rate (Zaharah and Razi, 2009). Decreases in the leaf area may be due to decreasing leaf elongation were consistent in agreement with the results of several studies on different plants (Peterson *et al*., 1991a, 1991b; Razi and Davies, 1998).

Physiological parameters

Table 3, show the effect of regular deficit irrigation water on some physiological parameters. It can be noticed that, sever deficit irrigation (70% IR) decreased leaf water content and relative water content significantly compared to the well watered treatment (100%IR) but it increased chlorophyll content. Also, sever deficit irrigation water significantly increased leaf proline content compared to the control (100% IR). While, well irrigated or moderate deficit irrigated trees showed a pronounced increase in leaf water content, relative water content and water use efficiency.

These results go in line with Da Silva *et al*., (2009) irrigated Tommy Atkins mango *cv*. at 90% IR increased water use efficiency and yield than irrigation at 70% of IR.

Flowering parameters

For the effect of regular deficit irrigation water on flowering behavior of "Keitt" mango trees (Table 4) it can be noticed that, decreasing irrigation levels significantly decreased malformed panicles%, powdery mildew% compared to control (100% IR). While deficit irrigation levels didn't affect panicle length, full bloom date and flowering duration. It can be concluded that severe regular deficit irrigation (70%IR) produce high quality of panicle (free from diseases) but with low panicle branches number.

In the tropics, water stress for five week resulted in early and high flowering intensity of mango (Lu and Chacko, 1999). Also, soil moisture stress is responsible for flower induction in many fruit species such as mangosteen (Apiratikorn *et al*., 2012), lime (Southwick and Davenport, 1986) and litchi (Stern *et al*., 1998) under tropical conditions. Moreover, vegetative flushing during mango flowering inhibited their flowering (Kulkarni, 1991) and most perennial fruit trees do not flowering in vegetative growth period (Wilkie *et al*., 2008). Water stress delay the development of vegetative buds and stimulate the growth of floral buds (Sarker and Rahim, 2013). Also, Water stress advanced flowering by nearly 2 weeks in nearly 40% of buds (Nunez and Davenport, 1994).

Moderate water stress (85% IR) prevents more shoot initiation and trees with more carbohydrates which necessary for flowering. Also, water-

Table 1: Distribution of the irrigation water through the two seasons of study (2017 and 2018).

Month	Eto	Irrigation requirements (m^3 / tree / month)			Irrigation requirements (m^3 / feddan / month)		
		100%IR	85%IR	70%IR	100%IR	85%IR	70%IR
January	2.18	0.43	0.36	0.30	171.50	145.00	120.00
February	3.11	0.60	0.51	0.42	240.00	204.00	168.00
March	4.23	0.86	0.73	0.60	345.00	293.00	241.00
April	5.75	1.20	1.02	0.84	480.00	408.00	336.00
May	6.83	1.65	1.40	1.16	660.00	561.00	462.00
June	7.47	1.95	1.66	1.37	780.00	663.00	546.00
July	6.69	1.65	1.40	1.16	660.00	561.00	462.00
August	6.42	1.65	1.40	1.16	660.00	561.00	462.00
September	5.42	1.25	1.06	0.88	501.00	425.00	350.00
October	4.01	0.89	0.76	0.63	357.00	303.00	250.00
November	2.42	0.51	0.43	0.36	204.00	173.00	143.00
December	1.93	0.39	0.33	0.27	155.00	132.00	108.50
Total (M^3 / year)		13.03	11.07	9.12	5213.50	4429.00	3648.50

Table 2: Effect of regular deficit irrigation on vegetative growth of “Keitt” mango trees during two seasons (2016/2017-2017/2018).

Parameter	Irrigation requirement					
	100%IR		85%IR		70%IR	
	2017	2018	2017	2018	2017	2018
Leaves number	10.7a	12.3a	11.7a	12.0 a	11.7a	11.7a
Leaf area (cm^2)	71.7a	76.7a	71.7a	77.3a	67.0a	62.0 b
Shoot diameter (cm)	8.7 a	8.3 a	7.7 a	7.3 ab	6.3 b	6.0 b
Shoot length (cm)	29.3 a	30.0 a	27.0 a	28.3 b	29.3 a	27.0 c
Flushes Number	2.3 a	1.3 a	2.0 a	1.7 a	2.3 a	1.3 a

Values followed by the same letter (s) in each column are not statistically different at 5 % level.

Table 3: Effect of regular deficit irrigation on some physiological parameters of “Keitt” mango trees during two seasons (2016/2017-2017/2018).

Parameter	Irrigation requirement (IR)					
	100%IR		85%IR		70%IR	
	2017	2018	2017	2018	2017	2018
Water use efficiency (kg/m^3)	1.27 a	0.76 b	1.1 a	1.09 a	0.054 a	0.92 ab
Leaf proline (µmoles/g)	0.0215 b	0.0217 b	0.0305ab	0.0309 a	0.0330 a	0.0338 a
Leaf water content (%)	68.0 a	73.00 a	66.00 a	69.00 b	63.00 b	68.00 b
Relative water content (%)	80.00 a	82.00 a	78.00 a	80.0 ab	75.0 b	78.0 b
Leaf chlorophyll	52.0 a	49.7 ab	46.7 b	47.3 b	52.3 a	51.3 a

Values followed by the same letter (s) in each column are not statistically different at 5 % level.

Table 4: Effect of regular deficit irrigation on flowering of “Keitt” mango trees during two seasons (2016/2017-2017/2018).

Parameter	Irrigation requirement (IR)					
	100%IR		85%IR		70%IR	
	2017	2018	2017	2018	2017	2018
Panicle Length	37.7a	38.0 a	37.3 a	38.7 a	37.3 a	36.0 a
Full bloom	95.7 a	94.7 a	98.3 a	95.0 a	97.0 a	96.0 a
Beginning of flowering	88.7 a	81.3 a	88.7 a	83.3 a	88.7 a	83.0 a
Flowering Duration	7.0 a	13.3 a	9.7 a	11.7 a	10.3 a	13.0 a
Malformed panicle %	11.7a	8.3a	6.7ab	5.0ab	1.7b	1.7b
Powdery mildew %	6.11a	8.3a	6.7ab	5.0ab	1.6b	1.6c
Panicle branches Number	37.7 a	34.3 ab	34.3 b	36.3 a	34.0 b	31.7 b

Values followed by the same letter (s) in each column are not statistically different at 5 % level.

stressed trees flowering more than well-watered trees, which produce more vegetative flush (Davenport, 1993; Schaffer *et al*., 1994).

Fruiting parameters

Table 5, indicted the effect of regular deficit irrigation on fruiting of “Keitt” mango trees. It can be observed that, sever deficit irrigation (70% IR) decreased significantly fruit number per tree and fruit yield (kg/tree). Also, sever (70%IR) and moderate (85%) deficit irrigation delayed maturity and increased sunburn damage.

Sunburn damage may be decreased under well watered and moderated deficit irrigation due to more leaf area and number which avoid fruit from direct sunlight. Also, It may be resulting from more relative humidity due to more transpiration and soil evaporation under well watered and moderate deficit water.

These results were agreed with Spreer *et al*., (2007) who reported that, water deficit in the early stage of fruit growth increased fruit drop in *cv.* ‘Chok Anan’ mango. Also, Whiley *et al*., (1989) found that Kensington Pride grew more at moderate high temperatures, at the expense of accumulating reserves. Depletion of stored starch in sensation mango *cv.* were drastically depleted during vegetative growth, flowering and fruit growth (Davie *et al*., 2000).

While, under sever deficit irrigation plant roots produce ABA as a hormonal signal to the shoot for reducing stomatal aperture (Hartung *et al*., 2002). Also, at early stages of mango development ABA is involved in fruit drop which resulted in decrease fruits number per tree. Increasing ABA have been found in mature mangoes (Kondo *et al*., 2004). Water deficit at the early stage of fruit development increased fruit drop in mango (Spreer *et al*., 2007). Moreover, severe deficit irrigation at flowering stage had a detrimental effect on pollination then fruit set (Lu and Chacko, 1997; González and Blaikie, 2003), which might negatively affect productivity. Sever deficit irrigation (70%) produced low number of branches per panicle then low fruit number.

For moderate deficit irrigation pre-flowering might enhance flower development (Davenport and Nuñez-Elisea, 1997; Lu and Chacko, 2000; Bally *et al*., 2000). Since, in tropics dry period is needed for restrain growth and stimulate flowering (Chacko, 1986; Lu and Chacko, 2000). However, in Tommy Atkins cultivar soil water deficit alone does not stimulate flowering (Da Silva *et al*., 2009).

Table 5: Effect of regular deficit irrigation on fruiting and productivity of "Keitt" mango trees during two seasons (2016/2017-2017/2018).

Parameter	Irrigation requirement (IR)					
	100%IR		85%IR		70%IR	
	2017	2018	2017	2018	2017	2018
Initial fruit set	3.3 a	4.3 a	4.3 a	4.7 a	3.3a	3.7 a
Final fruit set	1.0 a	2.0 a	2.0 a	1.7 a	0.7 a	1.7 a
Fruit retention %	30.3 a	46.7 a	48.3 a	35.0 a	22.0 a	50.0 a
Sunburn fruit %	36.3 a	43.3 a	38.3 a	46.7 a	37.3 a	56.7 a
Maturity date	308.0a	276.0b	312.3a	278.0ab	310.0a	279.3a
Number of fruits/tree	20.0 a	16.0 ab	21.7 a	20.0 a	15.0 b	13.7 b
Yield (Kg/tree)	14.0 a	10.0 ab	14.0 a	12.0 a	10.0 b	8.3 b

Values followed by the same letter (s) in each column are not statistically different at 5 % level.

Table 6: Effect of regular deficit irrigation on fruit quality of "Keitt" mango trees during two seasons (2016/2017-2017/2018).

Parameter	Irrigation requirement (IR)					
	100%IR		85%IR		70%IR	
	2017	2018	2017	2018	2017	2018
Fruit weight(g)	706.3a	623.3 ab	651.6 a	636.6 a	679.0 a	603.3b
Fruit diameter (cm)	9.30 a	9.27 ab	9.70 a	9.40 a	9.77 a	9.03 b
Fruit length	13.00 a	12.23 a	13.17 a	12.30 a	12.83 a	12.13 a
Fruit volume (cm^3)	626.67 a	535.00 ab	556.67 b	556.67 a	583.33 ab	516.7 b
Pulp weight (g)	550.00 a	503.33 a	520.00 a	523.00 a	533.3 a	496.7 a
Peel weight (g)	75.00 a	68.33 a	66.67 a	63.33 ab	69.3 a	55.0 b
seed weight (g)	81.33 a	51.67 a	65.00 a	50.00 a	76.33 a	51.67 a
Titratable acidity	0.80 a	0.87 a	0.80 a	0.83 a	0.77 a	0.83 a
Total sugars%	6.00a	6.67 a	6.67 a	7.00 a	6.67 a	6.67 a
TSS	12.00 b	12.33 a	13.33 a	12.67 a	13.33 a	13.00 a
Vitamin C content mg/ 100gm	36.33 a	36.33 a	36.33 a	36.33 a	36.00 a	36.00 a

Values followed by the same letter (s) in each column are not statistically different at 5 % level.

Fruit quality

ty (Castel and Buj, 1990; Peng and Rabe, 1998; Gonza´lez-Altozano and Castel, 1999; Hutton et al., 2007).

Water stress during either initial or final stage of fruit growth delayed size increases in lemons (*C. limon*), without affect the yield (Torrecillas *et al*., 1993). Also, Clementine mandarin yields may be decreased by water stress application at an early stage of fruit development through increasing fruit drop, while water stress applied at a later stage decreased fruit weight and yield (Gonza´lez-Altozano and Castel, 1999).

Generally, increasing yield due to irrigation occurs due to higher crop load rather than larger fruit size (Pavel and de Villiers, 2004; Spreer *et al*., 2006). Deficit irrigation at maturity stage, decreased fruit weight and size but it increased titratable acidity and total soluble solids (Treeby *et al*., 2007). Well watered mango trees (100%IR) contain more LWC and RWC and make the plant more susceptible for the panicle infection. Also, increasing IRL permit more relative humidity from plant transpiration and soil evaporation which is necessary to the infection of powdery mildew a (Joubert *et al.*, 1993; NasIRL *et al.,* 2014; Schoeman *et al.*, 1995) and malformation (Chakrabarti and Kumar, 1998) .

It can be concluded that, sever deficit irrigation (70%) decreased panicle infection with malformation and powdery mildew. Also, it decrease vegetative growth and yield with small effect on fruit quality. On the other hand, well watered trees (100%) increased vegetative growth, yield but it increased powdery mildew and malformation. So, moderate irrigation levels (85%) produce a sufficient vegetative growth which increased yield, maintains fruit quality and increased water use efficiency.

Acknowledgment

The authors thank Cairo university funding & A.I. EL Sewesy's private farm (trees, Fruit) for the use of orchard and facilities' to carry out the study.

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