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Impact of irrigation intervals with fertigation timing on Washington navel orange tree productivity and leaf nutrient content.

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ABSTRACT

Recently, as a result of citrus trees in some Nubaria region expose to intermittent forced irrigation, study in Egypt evaluated the effects of prolonged irrigation intervals and fertilizer doses timing , on twelve-year-old Washington navel orange trees on sour orange, under drip irrigation system (Nile river water) in Al- Bustan region, El-Behira governorate during 2020, 2021and 2022 seasons. Ten treatments contained T0: every day and fertigation done 30 min- before end irrigation period (control), T1, T2, T3 were every two, three and four days, respectively. Each of T1, T2, T3 had three timing of fertigation (a) 15 min - after beginning, (b) at middle time and (c) 15 min - before the end of irrigation period. Treatment were arranged in complete randomize block design. Irrigation every four days plus fertilizers at the 3rd time significantly increased leaf proline content, reduced fruit peel %, TSS %, TSS/Acid ratio &V.C .Irrigation every three days plus fertilizers at the 3rd time improved leaf macro-elements% , fruit weight, number of fruits, yield as kg / tree and reduced juice acidity. Irrigation every two days plus fertilizers at the 3rd time gave highest number of fruitlets in May, then decreased and fixed in June & July. Control treatment significantly reduced fruit-splitting% during August, September, October &November, while irrigation every four days plus fertilizers at the 1st time was the highest. Moreover, the highest fruit-splitting values noticed at September for all studied treatments. Irrigation every two days plus fertilizers at the 1st time increased fruit juice.

Key words: Navel orange, irrigation intervals, Fertilizer times, yield & fruit-splitting%.
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INTRODUCTION

In spite of suitable condition of soil type and climate of Delta for growing Washington navel orange trees, but suffer from some problems i.e. high levels of agricultural drainage water as a result, trees have become infected with many soil diseases, poor soil fertility, tree age,…etc., leading to deterioration in tree productivity, which promoted producers to plant in alternative regions. Desert regions such as Al- Bustan/El-Behira governorate in Egypt, are classified into new reclaimed soils (under semiarid regions) where dry hot climate and sandy or calcareous soils have low water and nutrient- holding capacity.

Water and fertilizer supply are considered to be a limiting factors for tree production, growth and yield. So, water-saving irrigation technique and fertilizer strategies could be used to improve water uptake efficiency and fertilizer in citrus trees (Quinones etal., 2003).

Nitrogen (N) application at optimal time through the drip irrigation during irrigation periods will resulting in reducing fertilizers leaching out root-zone and minimize ground water contamination with nitrate (No_3^{-}) over which limit of 10 ppm No_3-N; (National Institutes of Health U.S. Department of Health, Education, and Welfare, 1962).Using different strategies is a key concept to solve the problem of water scarcity.

Moreover, citrus orchards fertigation management might be beneficial to limit excessive root and vegetative flush growth) Yuan et al., 2005) .Whereas, fertilizer rates can change root density of grapefruit trees (*Citrus paradise*, Macf.) (Zhang etal., 1998). Thus, drip irrigation system can be used for nutrient

applications (fertigation), through which crop nutrient requirements can be met accurately through mixing liquid fertilizer with irrigation water.

Irrigation water and nutrient elements must be applied in optimized timing for crop demand to get maximum utilization. Moreover, fertigation system aims at saving fertilizer usage and reducing leaching losses (Kumar et al., 2007). Similar, to frequent applications of water, optimum split applications of fertilizers improves quality and quantity of fruit yield than conventional practice.

There is lack of information on the optimal irrigation intervals with fertilizing application and time of management techniques for Washington navel orange trees under Al Bustan region. Also, there's shortage in seasonal water requirements or irrigation intervals knowledge of orange trees grown under drip irrigation system, Schumanetal. (2009).Also, random water applications could be has a negative effect on tree growth, which reflected on final product. In additions, intensively managed fertigation systems, in which trees are fertigated as frequently as every 2, 3 or 4 days; have been proposed as a tool to increase water and nutrient uptake efficiency (Schuman et al., 2009).

As result of water do not reach to endings of some Nubaria Canal branches at appropriate level; this led to region subjected to intermittent forced irrigation. Hence, this study was undertaken to examine prolongation intervals between irrigation with fertigation at different timing on yield, fruit quality, and fruit splitting%, leaf nutrients status, and leaf proline content of Washington navel orange trees under Nubaria region conditions.

MATERIAL AND METHODS

This study was conducted in a private orchard located at Al- Bustan region, El-Behira governorate, Egypt during three successive seasons (2020, 2021 and 2022), respectively. Sixty-12years old mature Washington navel orange (*Citrus sinensis*, Osbeck) trees, budded on sour orange (*Citrus aurantium*, L.) rootstock were carefully selected for tree growth vigor and uniform size , spaced 4× 5 m. apart (210 trees/fed.) under drip irrigation system (includes squeeze pump (50 Hp) + sand and screen filters plus fertilizer injector units) "Nile water". The conveying pipe-line system consists of PVC tube "63 mm." as a main line, connected to PVC tube "50.8 mm." as sub-main line equipped with PE manifold "38.1mm" plus PE drip lateral "16 mm." in diameter. Each PE lateral line built-in emitters "4L/h discharge rate" spaced at 0.5 m, two lateral drip lines per trees raw include 6 emitters / line that are a 12 emitters/ tree. Soil samples at 0-30, and 30-60 cm. depths were collected to determine some physical and chemical characteristics are shown in Table (1.a & b), according to FAO (1970), Page et al. (1982) and Bulk and Hartge (1986).

Table (1.a) Experimental site physical soil analysis.

Soil depth (cm)	Bulk density (g cm^{-3})	Hydraulic conductivity (cm h^{-1})	Particle size distribution			Texture
			Sand %	Silt %	Clay %	
0 -30	1.63	212.46	92.2	4.0	3.8	Sandy soil
30 -60	1.64	228.60	94.2	2.4	3.4	Sandy soil

Table (1.b). Experimental site chemical soil analysis.

Soil depth (cm)	ECe dSm-1	PH 1:2.5	Total $CaCO_3$ (g /Kg-)	Soluble cations (m mole L-1)				Soluble anions (m mole L-1)			
				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4
0 -30	0.68	8.89	18.4	1.5	1.00	4.19	0.18	1.5	1.5	3.5	0.37
30 -60	0.72	8.91	14.9	2.0	1.50	3.66	0.22	2.0	1.5	3.0	0.88

Experimental treatments seasonally began in the 2nd week of February, tree water requirements about 20m3 during the season. Taking in consideration, water applications gradually increased in spring and summer " maximum tree water requirements ", then, gradually decreased during autumn, whereas, the minimum amounts of irrigation water were applied during winter. Trees were received 3hr: 20min per irrigation cycle during the summer and about120-160 min during spring or autumn months. While, the control treatment was daily irrigated for 2hr/day during the summer and about 80 min-100 min during the spring or autumn months. All studied treatments during winter season (1st Nov. - 2ndweek of Feb.), were irrigated at the rate 45min every 3 days. Approximately, total water consumption for T0: control (daily irrigation) ~ 20580 L/tree/season; T1: irrigated every 2 days ~ 17280 L/tree/ season; T2: irrigated every 3 day~ 12000 L/tree/season; T3: irrigated every 4 day~ 9888L/tree/season.

Nutrient elements were applied as the recommendations of Annual Bulletin of Ministry of Agriculture (2014 & 2019), beside humic acid was applied once every two months at a rate of 2 kg/fed. (Table 2).

Table (2). Nutrient elements applied for the control as the recommendations of Ministry of agriculture (2014 & 2019)/ seasons.

Stage	Date	Fertilizer forme	Fertilizers rate (Kg/week/Fed.)
Flushing, Blooming & fruit set.	1st March-15 May	Ca NO_3 (15.5% N)	8.5 Kg
		$(NH_4)2\ SO_4$ (20.6%N)	12.5 Kg
	15 May –end May	NH_4NO_3 (33.5% N)	9.0 Kg
	15 April-end May	K_2SO_4 (48.5 % K_2O)	6.70 Kg
		Mg SO4 (17.5 % MgO)	4.25 Kg
	1st March-end April	Phosphoric acid (85%P2O5)	2.00 L
Fruit growth & colour break	1st June – 15 June		9.0 Kg
	15 June- 15 July	NH_4NO_3 (33.5% N)	5.0 Kg
	15 July- 15 Aug.		11.0 Kg
	15 Aug.-end Sep.	(NH4)2 SO_4 (20.6% N)	15.0 Kg
	15 July- end Sep.	K_2SO_4 (48.5 % K_2O)	8.50 Kg
		Mg SO_4 (17.5 % MgO)	2.50 Kg
	15 June-15 July	Phosphoric acid (85%P_2O_5)	4.00 L
Fruit maturation & ripening	1st Oct.-end Oct.	$(NH_4)2\ SO_4$ (20.6% N)	15.00 Kg
	1st Oct.-end Nov.	K_2SO_4 (48.5 % K_2O)	15.00 Kg
		Mg SO_4 (17.5 % MgO)	6.25 Kg

Treatments and Experimental design:

The study included ten different treatments of irrigation intervals with different fertilizer timing during irrigated period as follow:

T0: Control; daily irrigation with farmer fertigation at last thirty minutes irrigation T1: Irrigated every 2 days & T 2: irrigated every 3 days and T 3: irrigated every 4 days with fertilizer application timing; (a) at1stof irrigated period (after 15 min of irrigation beginning), (b) at 2ndof irrigated period (middle of irrigation period), (c) at3rd of irrigated period (15 min before the end of irrigation period).The treatments were arranged in Randomized Complete Block Design (R.C.B.D) for distributing in orchard. Each block contains 10 groups (3 irrigation intervals × 3 timing of fertilizer application) plus control treatment. Each group represents an independent treatment; consisting of 5 trees, 2 only were selected as one replication (2 tree /replicate) of treatment. Each treatment was separated from the next one by a valve to control closing and opening of irrigation. Total number of trees used in this study was 60 trees (3 blocks × 10 treatments × 2 trees).

To ensure that treatment with the same irrigation interval and different timings for fertilizer application receive a full irrigation cycle; i.e. 3 hours through summer season without interruption, irrigation is firstly opened for fertilizer

application (c), followed by 75 min later, irrigation is opened for fertilizer application (b) and another 75 min, irrigation opened for fertilizer application (a) for 15 min. Hence, the fertilizer is supplied to the branch irrigation lines via Venturi injectors. Irrigation cycle is firstly completed after fertilizer applied about 15 min for treatment(c), then after 1hr: 30 min irrigation cycle of fertilization treatment (b) completed, lastly, after 2hr and 45 min for fertilization treatments (a).

1- Physiological studies:

At the end of the experiment of each season, in mid-October; sample of 20-30 full-expanded mature leaves was collected from non- fruiting spring shoots (from all over the circumference of each tree); washed with tap water; rinsed three times in distilled water and air dried .Samples were oven dried at 65- 70c° to a constant weight, then, ground to 20 mesh size.

a. Leaf macro-nutrients (N, P, K, Ca, Mg %):

- 0.3 gm ground dry weight was digested with sulfuric acid and hydrogen peroxide according to Evenhuis and Dewaard (1980).
- N & P: were color-meterically determined according to Evenhui (1976) and Murphy and Riley (1962).
- K: was determined using flame photometer.
- Ca & Mg: were determined by the Versenate method using eriochrome black T and ammonium purpurate indicator for Ca plus Mg & Ca, respectively according **to Cheng and Bray (1951).**

b. **Proline (amino acid) estimation**:

Proline was extracted from 0.5 gm ground dry material using the procedure suggested by Marin et al.(2009).

2- Tree yield & productivity:

a) Fruitlets number/branch during May, June & July:

During spring flushes 4 branches (at 4 different directions) were tagged/tree. The circumference of chosen branches was 4.5 cm. Number of fruitlets/branch at petal-fall stage, then, at the end of: May, June & July were recorded.

b) Fruit splitting %:

Average number of fruits/replicate were estimated & recorded at the 1st week of August month. Then, during August, September, October and November, monthly fallen fruits were gathered / replicate and fruit splitting % were recorded as:

$$\text{Fruit splitting \%} = \frac{\text{No. of splitting fruit}}{\text{No. of total fruits}} \times 100$$

C) Tree yield as a number & weight:

At harvest time (the 4th week of December) fruit number per each replicate was estimated and recorded. At random 10 fruits /replicate were picked and weighed, then, tree yield as kg were calculated as:

$$\text{Tree yield (kg)} = \frac{\text{No. of fruits} \times \text{fruit weight (g)}}{1000}$$

3) Fruit quality:

At harvest time (the 4th week of December) at random 10 fruits /replicate were picked for some physical and chemical characteristic:

a. Fruit physical properties: average fruit: weight (g), shape index, peel %, & juice % (w/w) were determined and recorded.
b. Fruit chemical properties: average fruit juice: TSS %, TA %, TSS/ Acid Ratio and V.C. (mg/100g) were estimated, according to A.O.A.C. (2005).

4) Statistical Analysis:

The data were statistically analyzed using Randomized Complete Block Design (R.C.B.D) according to Snedecor and Cochran (1990).All data presented as percentages were subjected to arcsine transformation before using analysis of variance, while the means were differentiated using Duncan multiple range test at 0.05 levels as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

1- Physiological studies:

a) Leaf macro-nutrients (N, P, K, Ca & Mg %):

Data presented in **Table (3 & 4)** illustrated N, P, K, Ca & Mg % as follows:

- **Leaf (N, P&K) % contents :** when water irrigation was applied at two days intervals plus fertigation at the end of irrigation period treatment" T2.c" , data presented in **Table (3)** showed that it significantly improved navel orange leaves nitrogen "N" (2.56,2.62 & 2.59); phosphorus "P"(0.28, 0.25 & 0.23) and potassium "K' '(1.26,1.19 &1.18) contents as percentage respectively, as compared to other treatments and the control during the three seasons .At the same time, irrigation intervals period plus different fertigation time fluctuated in its negative effect.
- **Leaf (Ca & Mg) % contents:** As for this **respect**, data in **Table (4)** demonstrated that water irrigation applied at two days intervals plus fertigation at the end of irrigation **period** "T2.c" significantly increased navel orange leaf Ca (4.64% , 1.19%& 4.89%) values, as compared to other treatments under study during the three seasons . On the contrary, water irrigation applied at three days intervals plus fertigation at the 1st time of irrigation period " T3.a" significantly gave the lowest Ca % values. On the other side, the same previous mentioned irrigation interval with fertigation at the 2nd time of irrigation period " T3.b'' gave significant effect on the highest navel orange leaf magnesium (0.60%, 0.65% & 0.60%) content. While, different other irrigation periods plus other fertigation time fluctuated in its negative effect on leaf Mg % contents.

Undoubtedly**,** improving irrigation efficiency plus providing trees water requirements and fertilizers applications at a suitable time will be reflected on elements uptake and improved their concentration in leaves. Thus, these results are in harmony with those obtained by Castle and Buj (1990) and Peng and Rabe (1998) when leaf proline content increased, leaf N was decreased, this might explained that nitrogen concentration consumed in biosynthetic pathway of proline amino acid. Shirgure et al. (2012) reported that leaf nutrient status was high with automatic alternate day drip irrigation schedule and enhancing the water use efficiency by citrus trees. Panigrahi et al. (2012) confirmed that magnesium uptake efficiency was increased with increasing irrigation intervals, thus leaf magnesium content increased. EL-Tanany et al. (2019b) reported that leaf calcium concentration was markedly increased under deficit irrigation treatment at 80 and 100% of ETo when compared to water deficient stress at 60% of ETo and the differences were significant. In the contrast, Srivastava and Singh (2008) and Panigrahi et al. (2012) found that all the deficit irrigation regimes produced the higher concentrations of N, P and K. They attributed this increment to the higher tree uptake with increased availability of such in soil under deficit irrigation conditions.

b) Effect of irrigation intervals with fertilizers applications time on leaf proline contents:

Data in the **Table (4)** cleared that navel orange tree leaves small proline contents were more responsive to water irrigation application at the 4th day plus fertigation time at the end of irrigation period (T3.c) treatment. Whereas, this treatment significantly gave the highest leaf proline concentration values (2.44, 2.44 & 2.42), percentage respectively, as compared to other experimental treatments and the control during three studied seasons. On the other hand, daily irrigation plus fertigation at last thirty minutes (control treatment) " T_0" or irrigation day after day plus fertigation at the 1stirrigation time "T1.a" had the lowest values. It has been recognized that water irrigation deficit and salinity are considered as biotic stresses factors, proline as amino acid has a positive relationship with them, and used an index of stress, (Andriano et al., 2004).

Table (3). Effect of irrigation intervals with fertilizers application time on navel orange leaf (N, P, K) % contents during the three seasons.

		Season I			SeasonII			SeasonIII		
		N%	**P%**	**K%**	**N%**	**P%**	**K%**	**N%**	**P%**	**K%**
T_0	Control	1.82e	0.21c	1.10d	1.42h	0.19d	1.13b	1.62g	0.19c	1.13c
	a	0.93g	0.15f	1.15c	1.26i	0.14h	1.03d	1.66f	0.17e	1.11d
T1	b	2.25c	0.19e	1.10d	1.56f	0.20e	1.03d	1.091e	0.20b	1.07e
	c	1.56f	0.20d	1.22b	1.76d	0.16f	1.12b	2.02d	0.18d	1.18a
	a	1.92d	0.14g	1.09d	1.89e	0.18e	1.12b	2.11e	0.18d	1.07e
T2	b	2.40b	0.24b	1.23b	2.30h	0.22e	1.10c	2.22b	0.20b	1.17b
	c	2.56a	0.28a	1.26a	2.62a	0.25a	1.19a	2.59a	0.23a	1.18a
	a	1.82e	0.19e	1.07e	2.48g	0.18e	0.78f	1.59g	0.17e	0.79h
T3	b	1.90d	0..19e	0.80g	1.61e	0.20e	0.88e	1.69j	0.19e	0.93g
	c	1.57f	0.15f	0.84f	1.20j	0.15g	1.04d	1.07h	0.17e	1.02f
LSD		0.04	0.003	0.011	0.03	0.003	0.013	0.04	0.01	0.009

Values having the same letter(s) within the same column are not significantly different at 5% level.

Table (4). Effect of irrigation intervals with fertilizers application time on navel orange leaf Ca%, Mg% and proline (mg/dw) contents during the three seasons.

		SeasonI			SeasonII			SeasonIII		
		Ca%	**Mg%**	**Proline (mg/dw)**	**Ca%**	**Mg%**	**Proline (mg/dw)**	**Ca%**	**Mg%**	**Proline (mg/dw)**
T_0	Control	4.11c	0.32de	1.46i	1.12b	0.30g	1.01h	4.37c	0.37g	1.23h
	a	3.80d	0.43bc	1.26j	1.13b	0.63b	1.14g	4.41c	0.32h	1.21h
T1	b	4.16c	0.26e	1.51h	1.03d	0.21i	1.25f	4.34c	0.50b	1.43f
	c	4.41b	0.27e	1.55g	1.12b	0.57c	1.31e	4.14d	0.45d	1.28g
	a	4.11c	0.48b	1.76e	1.04d	0.46e	1.40d	4.69b	0.47c	1.58e
T2	b	3.52f	0.32de	1.60f	1.10c	0.47d	1.40h	4.14d	0.38f	1.83c
	c	4.64a	0.29e	1.90d	1.19a	0.19j	1.71e	4.89a	0.24i	1.63d
	a	3.16g	0.38cd	2.40b	0.78f	0.44f	2.22b	3.92e	0.41e	2.33b
T3	b	3.80d	0.60a	2.18c	0.88c	0.65a	2.47a	3.53g	0.60a	2.33b
	c	3.73e	0.38c	2.44a	1.04d	0.26h	2.44a	3.83f	0.32h	2.42a
LSD		0.066	0.009	0.034	0.120	0.008	0.04	0.0054	0.0094	0.034

Values having the same letter (s) within the same column are not significantly different at 5% level

Fertilizers applications at the 3rdirrigation period may cause an increase of salts through surface root area which contain about of 80% of tree roots. These results agree with those found by Hanson et al. (2006 b) and El-Tanany et al. (2019 b) found that timing of adding fertilizers at the end of irrigation may represent salt stress in the long-term and water irrigation deficit significantly raised leaf content of proline amino acid compared to other deficit irrigation treatments.

2- Tree yield & productivity:

a) Fruitlets number / branch during May, June &July:

Regard to the effect of treatments under study on the number of fruitlets for navel orange during fruit setting stage (May, June & July) data tabulated in **Table (5)** revealed that, in general, the number of fruitlets/ branch significantly had the highest values in May and the lowest in July. Moreover, water irrigation applied at one day intervals with fertigation at the 3rd time of irrigation period "T1.c"in May significantly has the highest values during three studied seasons (47.63, 55.63 & 45.38) fruitlets respectively. When compared to other treatments. As for June, the highest fruitlets values resulted in water irrigation applied at three days intervals with fertigation at the 3rd time of irrigation period "T2.c'' (14.70, 17.60& 11.50) fruitlets, respectively. Finally, the same treatments " T2.c" gave the same trend in July (12.50, 6.90 & 9.50) fruitlets respectively, for the experimental seasons. Results also, indicated that the lowest navel orange fruitlets number varied as for treatments effect during studied seasons, but the lowest number related with prolonging intervals between irrigation with fertigation timing under study. These results are in agreement with those mentioned by Romero et al. (2006) and Zaghloul et al. (2015) where reported that the reduction of fruits trees that exposed to water stress; decreasing or increasing soil moisture content during flowering, fruit setting and early stages of fruit growth (early May to mid-June) may subject roots to insufficient water which caused increment of fruit dropping% especially, June-drop period, so to avoid that stress, soil must be kept fairly wet during summer months. Moreover, Kumar et al. (2007) and Sharma et al. (2011) showed that application of water at optimum case plus split application of fertilizer improves quantity and quality of crop yield (including fruit set)whereas, fertigation ensures substantial saving in fertilizers usage and reduces leaching losses.

b) Fruit splitting %:

As for the effect of irrigation intervals with fertilizers applications time on fruit splitting % of navel orange trees, data presented in **Table (6)**cleared that daily water irrigation plus fertigation at last thirty minutes before end irrigation (control'T0'**)** resulted insignificant difference the lowest fruit splitting (0.00) percentage during August, September, October & November for the three seasons, respectively. Whereas, water irrigation every four days with fertigation at the 1st time of irrigation period treatment " T3.a" significantly gave the highest fruit splitting % during August (1.14%), September (2.37%), October (1.21%) and November (0.41%) during the three studied seasons. Moreover, data revealed that the highest fruit splitting % for all experimental treatments took place at September for experimental seasons. Our findings are matching with Romero et al. (2006) where noticed that citrus fruit on trees that have been under water stress can grow faster after re-watering than fruit on regularly watered trees, in response to create a greater water uptake force and reflect in compensatory growth of fruit and a more negative water potential in the fruit growth. So, practically, citrus fruit splitting at fruit cell enlargement and before maturation depends upon cell water contents, nutrient status, hormonal balance, etc. thus a suitable water irrigation applications plus optimum fertilizers application should result in reducing fruit splitting during this stage. Previous results were a similar with those obtained by Rubino et al. (2004) showed that, physiological disorder (creasing, splitting and scald) of citrus fruits are associated with water shortage and water irrigation quality.

Table (5). Effect of irrigation intervals with fertilizers application time on fruitlets number/branch of navel orange tree during the three seasons.

		SeasonI			SeasonII			SeasonIII		
		May1st	**June1st**	**July1st**	**May1st**	**June1st**	**July1st**	**May1st**	**June1st**	**July1st**
T_0	Control	26.90h	7.80c	7.15b	37.63d	7.50c	5.90b	26.30f	9.25d	7.30c
	a	36.53e	7.90d	3.55g	48.13b	6.50d	4.63d	29.50e	5.50j	4.63ef
T1	b	39.08d	7.38e	4.60f	47.88b	6.38d	4.38e	24.50g	6.25hi	4.80de
	c	47.63a	8.50c	6.50c	55.63a	9.13b	6.00b	45.38a	8.13ef	5.00d
	a	35.08f	7.00f	3.40i	38.13d	6.50d	2.13h	23.80g	7.38g	8.00b
T2	b	20.50i	10.0b	7.13b	26.13g	6.50d	3.00g	34.38c	10.50b	7.80b
	c	46.00b	14.70a	12.50a	46.00c	17.60a	6.90a	33.13d	11.50a	9.50a
	a	39.53cd	6.40g	5.33e	33.63e	6.63d	5.50c	40.00b	6.13i	4.38f
T3	b	32.33g	6.63g	5.80d	25.00g	7.00cd	3.80f	26.88f	8.00f	7.40c
	c	20.50ij	6.03h	4.08h	27.50f	6.50d	3.88f	15.88h	9.25cd	3.38g
LSD		1.35	0.33	0.15	1.26	0.72	0.23	0.87	0.25	0.26

Values having the same letter(s) within the same column are not significantly different at 5% level

Table (6). Effect of irrigation intervals with fertilizers application time on fruit splitting % of navel orange tree during the three seasons.

		SeasonI				SeasonII				SeasonIII			
		Aug	**Sept.**	**Oct.**	**Nov.**	**Aug**	**Sept.**	**Oct.**	**Nov.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**
T_0	Control	0.00g	0.20g	0.33e	0.27f	0.00h	0.00i	0.00f	0.00d	0.00h	0.40h	0.11g	0.00f
	a	0.85 b	1.17d	0.20f	0.14f	0.60f	0.85h	0.00f	0.00d	0.68d	0.78d	0.00h	0.00f
T1	b	0.67c	2.24b	0.88c	0.18e	0.82d	1.46e	0.41e	0.00d	0.55e	0.72g	0.47d	0.00f
	c	0.23f	1.15d	0.84c	0.00g	0.46g	1.51d	0.58d	0.00d	0.00h	0.95f	0.00h	0.27e
	a	0.84b	1.80c	0.33e	0.30d	0.68e	1.20f	0.71c	0.22c	0.73d	1.09e	0.26f	0.37d
T2	b	0.33e	0.81f	0.86c	0.22e	0.55f	0.98g	0.39f	0.36b	0.11g	0.81g	0.37e	0.27e
	c	0.53d	2.39a	0.94b	0.33c	1.08b	2.50c	0.55d	0.00d	0.73d	1.48d	0.65c	0.53b
	a	1.14a	2.37a	1.21a	0.41b	1.71a	3.76a	1.87a	0.83a	1.09b	1.89c	2.01a	0.65a
T3	b	1.13a	1.08e	0.49d	0.68a	0.77d	2.85b	1.13b	0.36b	1.63a	3.02a	0.35e	0.45c
	c	1.14a	2.25b	0.90b	0.41b	1.02c	2.50c	1.13b	0.82a	0.96c	2.27b	1.22b	0.37d
LSD		0.04	0.08	0.06	0.03	0.06	0.02	0.06	0.04	0.05	0.09	0.08	0.03

Values having the same letter(s) within the same column are not significantly different at 5% level

c) Tree yield as a number & weight (kg/tree)

Concerning the effect of irrigation intervals with fertilizers application time on tree yield (number. &weight.) of navel orange trees data, tabulated in **Table (7)** statistically cleared that water irrigation application at two days interval plus fertigated at the 3rd period of irrigation period treatment "T2.c" gave the highest with significant difference in both number of fruits (200.00, 198.00 & 218.00) fruit / tree and tree yield (kg) (39.99, 42.14 & 42.85) kg/tree compared to all other experimental treatments for the three studied seasons. This could be because the roots of trees grown under moderately drought-stressed, spread to explore more soil volume than well watered roots, once roots have restored the root-to-shoot ratio, positively affect photosynthesis rate, and shoot and fruit growth will resume Syvertsen and Hanlon (2008).While, water irrigation application at three days interval plus fertigated at the 3rd period of irrigation period treatment "T3.c" was the lowest, it may be to the fact that the rate of flow and infiltration of irrigation water and dissolved nutrients through soil that subjected to water deficiency is faster than rate of absorption by the tree root system, and reflected negatively on growth and yield. These findings are in agreement with those obtained by EL-Sayed and Ennab (2013) and Hussien et al. (2013) indicated that a gradual reduction in fruit number/tree and yield were observed as the amount of irrigation water decrease, Zayan et al. (2016) and Zaghloul and Moursi (2017) demonstrated that moderate irrigation treatment as appropriate program for increased number of fruits/tree and yield as kg / tree.

3) Fruit quality:

a. Fruit physical properties:

Navel orange fruit physical properties i.e. fruit: weight, peel % (w/w), juice % (w/w) &shape index were significantly affectedly different water irrigation intervals with fertilizers application time treatments whereas, data presented in **Table (8)** revealed that trees (i) irrigated at two days intervals and fertigated at 3rdtime of irrigation period “T2.c” significantly gave the highest fruit weight(200.30, 212.50 & 217.30) gm. as compared to other treatments under study for the three studied seasons.

On the other side, trees irrigated at three days intervals and fertigated3rdtime of irrigation period “T3.c” was the lowest.(ii) trees irrigated every three days and fertigated at 1st time of irrigation period“ T2.a” significantly gave lower fruit peel % (w/w) (12.68, 12.03 & 13.33) in three seasons, respectively and trees irrigated every four days and fertigated at 3rd time“T3.c”were the lowest (8.97%) in second season., the significant highest fruit peel % (w/w) recorded where trees irrigated at one day interval and fertigated at 3rd time “T1.c” (28.34, 21.19 & 32.98).(iii) trees irrigated at one day interval and fertigated at the 1sttime of irrigation period “T1.a”significantly gave the highest fruit juice % (w/w) (45.91, 46.11 & 41.22) respectively, while data showed that water irrigation intervals periods considers the main factor in fruit juice contents therefore, trees irrigated at two or three days intervals gave the lowest fruit juice contents during the studied seasons.(iiii) finally, in spite of, experimental treatments under study caused a light effect on the two dimensions of Washington navel orange but, most of fruits /tree appeared at oval shape (fruit: height >diameter).

Table (7). Effect of irrigation intervals with fertilizers application time on tree yield (number of fruit/tree & weight kg/tree) of navel orange tree during the three seasons.

		SeasonI		SeasonII		SeasonIII	
		No. of fruit	**Weight (kg)**	**No. of fruit**	**Weight (kg)**	**No. of fruit**	**Weight (kg)**
T_0	Control	183.00c	35.46c	153.00d	28.77d	185.00d	36.13d
	a	185.00b	34.06e	136.00f	25.07f	192.00c	35.52e
T1	b	187.00b	34.75d	91.00i	17.09i	97.00h	16.99i
	c	186.00b	37.22b	183.00b	35.07b	183.00d	39.66b
	a	134.00f	24.82h	175.00c	33.31c	202.00b	37.17c
T2	b	155.00e	29.06g	119.00h	22.61h	111.00g	20.72h
	c	200.00a	39.99a	198.00a	42.14a	218.00a	42.85a
	a	171.00d	31.51f	129.00g	24.21g	166.00e	29.73f
T3	b	124.00g	21.74i	153.00d	26.26e	140.00f	23.77g
	c	94.00h	14.58j	140.00e	24.36g	96.00h	13.09j
LSD		3.00	0.50	3.00	0.56	3.00	0.44

Values having the same letter(s) within the same column are not significantly different at 5% level

Table (8). Effect of irrigation intervals with fertilizers application time on navel orange fruit physical properties during the three seasons.

		SeasonI				SeasonII				SeasonIII			
		Fruit wt. (g)	**Fruit peel%**	**Fruit juice %**	**Fruit shape index**	**Fruit wt. (g)**	**Fruit peel%**	**Fruit juice %**	**Fruit shape index**	**Fruit wt. (g)**	**Fruit peel%**	**Fruit juice %**	**Fruit shape index**
T_0	Control	193.90b	7.11e	34.12f	1.07a	188.30bcd	15.61d	38.50d	1.07a	195.00c	22.49d	35.72c	1.06a
	a	184.80b	21.77b	45.91a	1.08a	185.00d	17.95c	46.11a	1.10a	185.00e	25.57c	41.22a	1.12a
T1	b	186.00c	19.80c	34.14f	0.99a	186.30cd	20.30b	41.00c	1.03a	175.50h	28.39b	35.54c	1.06a
	c	200.00a	28.34a	37.34b	1.05a	191.30b	21.19a	42.39b	1.04a	196.30b	32.98a	38.26b	1.09a
	a	184.80d	12.68h	33.33g	0.98a	190.00bc	13.33f	35.87fg	1.05a	183.80f	12.03h	30.79f	1.02a
T2	b	187.00c	19.68c	36.07d	1.06a	190.00bc	20.31b	32.52h	1.05a	187.50d	17.67f	32.61d	1.05a
	c	200.30a	21.62b	33.27g	1.03a	212.50a	18.32c	35.59g	1.05a	217.30a	24.92c	30.96f	1.05a
	a	184.80d	18.62d	35.61e	1.05a	188.00bcd	14.75e	38.50d	1.06a	179.30g	13.91g	32.72d	0.99a
T3	b	175.30e	14.19g	37.18bc	1.07a	171.30e	11.25g	36.42f	1.05a	170.00i	19.40e	31.96e	1.04a
	c	155.70f	14.94f	36.85c	1.03a	174.60e	8.97h	38.16e	0.91a	136.30j	14.27g	27.27g	1.01a
LSD		1.20	0.56	0.42	0.10	4.09	0.570	0.60	0.19	1.08	0.74	0.48	0.15

Values having the same letter(s) within the same column are not significantly different at 5% level

b. Fruit chemical properties:

Data tabulated in **Table (9)** indicated that navel orange fruit chemical characters i.e. fruit juice: (TSS& TA) % ;TSS/Acid Ratio and V.C" mg/100g" were significantly affected by different water irrigation intervals with fertilizers application time treatments as follows: (i)trees irrigated at three days intervals and fertigated at the 3rd time of irrigation period "T3.c" significantly resulted in, the highest fruit juice TSS% (15.80;18.49 & 16.50) respectively, TSS/Acid Ratio (18.39 & 20.00) in second and third season and juice V.C (49.99; 50.49 & 51.77) mg/100g respectively, and trees irrigated at one days intervals and fertigated at the 3rd time of irrigation period "T1.c" was mostly lower for the three studied seasons.(ii)trees irrigated at two days intervals and fertigated at the 1st time of irrigation period"T2.a"significantly reduced fruit juice total acidity % (0.81,0.81&0.79) respectively, whereas, trees irrigated at three days intervals and fertigated at the 3rd time of irrigation period"T3.c" was the highest during experimental seasons . It's well known that good horticulture managements will reduce stresses had improve tree productivity and fruit quality. Thus, previous results were in agreement with those found by EI-Boray et al. (1995) demonstrated that fruit juice % recorded increased by increasing of irrigation level. Romero et al., (2006) explained the reduction in fruit growth in Phase I in response to deficient irrigation may be associated with translocation of water from the fruit to the transpiring leaves, leading to turgor loss in the fruit, which resulted in reduction in fruit length and diameter. Also, deficit irrigation treatment resulted in a lower mandarin fruit (pulp & peel) percentage. Schuman et al. (2009) and Sharma et al. (2011) mentioned that application of fertilizers with irrigation (fertigation) at the proper time of irrigation "at the 3rd time of irrigation" increased water and nutrient uptake and reduce leaching losses. Panigrahi et al. (2012) mentioned that deficit water irrigation could be impose desirable water stress on Nagpur mandarin tree by improving citric acid ratio, brix, juice content and thickness of peel. Shirgure (2012) reported that the increment in fruit length and diameter could be attributed to an adequate of water irrigation supply and nutrients through fertigation caused an increase or hastened of cell division rate (cell elongation and enlargement). Optimum water application plus split fertilizer improves tree yield productivity and quality. Also, Navarro et al. (2015) found that when water stress was applied during the stage of fruit growth, it negatively affected fruit size, weight, and yield and fruit maturation, while improving some quality parameters. Furthermore, Morianou et al. (2021) found that severe water stress during phase II (cell elongation and rapid fruit growth period) significantly decrease the fruit size of grapefruit varieties. They demonstrated it may be due to water-stressed citrus fruits accumulate less dry matter than those non-stressed because of active competition between the fruit tissue and other sink organs of the tree structure. Moreover, deficient irrigation during phase III of citrus development increased the TSS and TA of fruit juice values, and the fine balance of TSS and TA is a widely accepted method to determine citrus fruit maturation stage. In addition, attributed with significant increase of TSS and TA values under water stress condition due to novo biosynthesis of organic acids in an overall attempt to achieve osmotic adjustment in the fruit matrix. Yang et al. (2021) confirmed the previous finding and revealed that TSS and TA in fruit may be higher due to enhanced synthesis of organic solutes rather than a concentration impacts under water stress, suggesting a potential osmotic adjustment. Vitamin C content (ascorbic acid) was increased, and this might be attributed to the tree combat of the occurring water stress via the de novo synthesis of ascorbic acid. Aydinsakir et al. (2021) concluded that Valencia Late orange tree that exposed to reduced water amount was associated with higher vitamin C levels in fruit. They added high vitamin C content may function as a defense strategy against water stress and drought damages. On contrary, Zaghloul and Moursi (2017) reported that ascorbic acid decreased by increasing soil moisture. EL-Tanany et al. (2019a) mentioned that water stress at 60% ET_0 significantly reduced fruit vitamin C content when compared to control irrigation at 100%.

Table (9). Effect of irrigation intervals with fertilizers application time on navel orange fruit chemical characters during the three seasons .

		SeasonI				SeasonII				SeasonIII			
		TSS%	**TA %**	**TSS/ acid ratio**	**Vit. C mg/ 100g juice**	**TSS%**	**TA %**	**TSS/acid ratio**	**Vit. C mg/ 100g juice**	**TSS%**	**TA %**	**TSS/acid ratio**	**Vit. C mg/ 100g juice**
T_0	Control	15.30c	0.92d	17.33c	45.55c	17.69e	0.87d	17.06d	47.38c	15.00d	0.95c	17.77b	46.96c
	a	15.00d	0.84g	16.49e	43.75d	16.67g	0.85e	16.94de	41.24ef	14.50f	0.88e	15.31f	42.36f
T1	b	14.80f	0.91e	15.74f	41.69fg	16.19h	0.90c	16.11g	41.36ef	15.25c	0.80g	16.05e	42.36f
	c	14.30g	0.87f	17.59e	42.19ef	14.00i	0.82g	16.76ef	41.00f	14.75e	0.80g	14.50g	43.37e
	a	14.80f	0.81h	17.01d	42.86de	16.88f	0.81h	14.29i	41.44e	15.02d	0.79g	16.67d	46.26d
T2	b	14.90e	0.82h	14.74g	45.55c	17.70e	0.84f	16.67f	40.71g	14.50f	0.87f	17.24c	42.02f
	c	15.00d	0.84g	17.75b	40.80g	18.25c	0.95b	17.58b	44.13d	16.00b	0.97b	18.85b	40.89g
	a	15.50b	0.94b	16.48e	48.80b	17.84d	0.95b	17.39c	49.18b	15.23c	0.97b	17.78b	50.03b
T3	b	15.51b	0.93c	18.45a	49.88a	18.29b	0.90c	18.38c	47.02c	16.00b	0.99a	19.88a	51.63a
	c	15.80a	0.98a	17.76b	49.99a	18.49a	1.10a	18.39a	50.49a	16.50a	0.99a	20.00a	51.77a
LSD		0.04	0.005	0.240	0.930	0.040	0.009	0.190	0.360	0.050	0.009	0.290	0.400

Values having the same letter(s) within the same column are not significantly different at 5% level

Conclusion

Generally, it can be concluded that irrigation every 3 days under drip irrigation system with applied fertilizers at the 2nd or the 3rd stage of irrigation period for Washington navel orange orchards grown under Al- Bustan region conditions .This may be a superior treatment to improve leaf nutrient status, tree yield and fruit quality with saving irrigation water consumption during growth season. Taking into consideration that intermittent irrigation is not recommended in these stress-prone areas currently or in future under presence climate changes.

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تأثير فترات ما بين الري مع توقيت التسميد على إنتاجية شجرة برتقال سرة واشنطن ومحتوى الأوراق من العناصر الغذائية.

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قسم بحوث الموالح – معهد بحوث البساتين – مركز البحوث الزراعية

نتيجة تعرض أشجار الموالح فى بعض المناطق بالنوبارية للري المتقطع اضطراريا، هدفت الدراسة إلى تقييم الأشجار تحت إطالة فترات ما بين الريات وتوقيت جرعات الأسمدة على محتوى الاوراق من البرولين، بعض العناصر الكبرى ، إنتاجية الأشجار، بعض خصائص جودة الثمار ونسبة تشقق الثمار. تم استخدام أشجار برتقال ابو سرة واشنطن البالغة من العمر اثني عشر عاماً والمطعمة على أصل نارنج تحت نظام الري بالتنقيط (مياه نهر النيل) خلال ثلاث مواسم متتالية ٢٠٢٠، ٢٠٢١ و٢٠٢٢، لدراسة عشرة معاملات مختلفة تحتوى على فترات رى: (T0) كل يوم ويتم التسميد قبل ٣٠ دقيقة من نهاية فترة الري (الكنترول)، وكانت (T1) و (T2) و (T3) كل يومين وثلاثة واربعة ايام بالترتيب ،لكل منهم ثلاث توقيتات للتسميد (أ) ١٥ دقيقة - بعد البداية، (ب) فى منتصف زمن الرى و (ج) ١٥ دقيقة - قبل نهاية الري.

أشارت النتائج التي تم الحصول عليها إلى أن الري كل أربعة أيام بالإضافة إلى الأسمدة في التوقيت الثالث أدى إلى زيادة معنوية في محتوى البرولين في الأوراق، وانخفاض نسبة قشر الفاكهة وفيتامين سى، بينما الري كل ثلاثة أيام مع اضافة السماد فى التوقيت الثالث ادى الى تحسين تركيز العناصر الكبرى للأوراق؛ متوسط وزن الثمرة وعدد الثمار ومتوسط محصول الشجرة بالكم وانخفاض حموضة العصير، أعطى الري كل يومين مع إضافة الأسمدة في التوقيت الثالث أكبر عدد من الثمار في شهر مايو. أدت معاملة المقارنة إلى انخفاض معنوي في تشقق الثمار خلال أشهر أغسطس، سبتمبر، أكتوبر ونوفمبر، بينما كان الري كل أربعة أيام بالإضافة إلى التسميد في التوقيت الأول هو الأعلى. الري كل يومين بالإضافة للأسمدة في الفترة الأولى ادى الى زيادة العصير.