Water Budget Economy of Navel Orange Production under Screen Net

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ABSTRACT

Impacts of screen net on water consumption and physiological status of navel orange, *Citrus Sinensis*, was studied, in order to assess the economic benefits of shaded navel orange trees, reach water use efficiency and gain highest yield quality and quantity. A single span greenhouse was covered by screen net (25% initial shading) as compared to open field. Three irrigation levels (60, 80 and 100%) were adjusted as actual water (ETc) according to lysimeter tank, whereas the crop coefficient (Kc) was determined from the relationship between ETc and reference evapotranspiration (ET_o). Water applied at 80% water consumption enhanced fruit growth and quality, but it was not affected in the peak flowering period, creating significant positive effects for other yield parameters as well as water use efficiency (production per unit of water). The interaction, water applied at 80% water consumption under screen net trees save water during the two seasons were 34.4% (1614.4 m^3/acre) less than the open field (2458.0 m^3/acre). Meanwhile, water use efficiency was higher 29.2% and 26.6% for screen net than the open field 15.1 and 15.3% for both seasons, respectively. The economic assessment of costs and returns from different treatments were calculated. It was found that the average yield were higher under screen net compared to the open field. Gross margin per 720 m^2 were analysed using yield data, fruit price structures and production costs. Screen net with 80% irrigation level had the highest gross margin US$ 228.5 and US$ 249.38 (1 US$= 16 Egyptian pound) in the first and second seasons, respectively. The benefit cost analysis (BCA) per 720 m^2 were analysed, the screen net with 80% irrigation level had the highest BCA with 3.4 in the first season and 3.6 in the second season.

Keywords: *Benefit- cost analysis (BCA), ET0, Gross margin, Navel orange, Screen net, Water consumption.*

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1. INTRODUCTION

Citrus is a major export product of Egypt. In 2015, the total cultivated citrus area in Egypt was 533.8 thousand acres, of which 449.6 thousand acres are in production (Fruitful), with a total production 4.6 million tonnes/ year (Ministry of Agriculture and Land Reclamation (MALR), 2015). The volume of citrus exported to various countries during 2015 was 1.3 million tonnes (CAPMAS, 2015). The total cultivated area of orange in Egypt was 378.1 thousand acres. About 312.6 thousand acres are in production (Fruitful), with a total production 3.35 million tonnes (MALR, 2015). Navel orange is ranking the most important species cultivated (48 per cent) from the orange cultivated area, followed by summer Valencia (42 per cent) and Baladi (graft) orange (6 per cent) from the orange cultivated area (MALR, 2015).

Citrus, despite their tropical origin, could be grown in hot-dry areas. In some periods of the year, they do not receive optimal requirement of environmental conditions such as fluxes of radiant energy, air and soil temperature, relative humidity that led to the disturbance of water and nutrient absorption; thus, limiting their metabolic systems. Meanwhile, dust accumulations on the plastic cover during the summer reduce light transmission and limit photosynthetic function. Nevertheless, the establishment of citrus in diverse environments has often led to the adoption of unique cultural practices that modify the impact of adverse environment on the developed plant (Bruce and Peter, 1994; Germana *et al*., 2001; Refaie *et al*., 2012). Accurate measurements of the crop water status are becoming essential in irrigated agriculture, as water resources are limited and its use must be optimised, especially in semi-arid conditions (Gonzalez-Dugo *et al*., 2014).

In the case of citrus, maximum water requirements may be assessed with a simple model as function of ground cover (Villalobos *et al*., 2009). Often, the full water requirements cannot be satisfied and thus, deficit irrigation strategies are being imposed as water resource becomes increasingly limited. Deficit irrigation is also proposed as a strategy for increasing fruit quality (Ballester *et al*., 2011). During the last decades, due to increased air temperature and intensity of solar radiation caused by climate change, an increasing area of crops is being grown under shading materials of various types. Environmental stresses such as temperature and water deficits during critical periods of fruit development and maturation are known to influence fruit yield (Goldschmidt, 1999). In order to reach sustainable agriculture, it is particularly important to optimise crop production by minimising inputs, mainly water and nutrient. Water saving practices need to be adopted in intensive horticulture of arid and semi-arid regions, where there is strong competition for limited water supplies. Water efficiency is a key concept to solve water shortage problems (Abouatalah *et al*., 2012).

On the other hand, Citrus, in fact (Sinclair and Allen, 1982) as other tree crops, can affect yield and internal fruit quality especially (ratio of sugar to acid and TSS) with the increase of fruit average weight, diameter and improve mainly water use efficiency corresponding with the shading net under strategy of water regime (Iglesias and Alegre, 2006; Medany *et al*., 2009; Abouatalah *et al*., 2012; Refaie *et al*., 2012). Therefore, water balance is the most important aspect that crops have to tackle and it is influenced by the climate parameters that are controlled by shading materials.

Navel orange average yield under screen net was 18.9 tonnes/ feddan (4200 m^2), compared to12.3 tonnes/ feddan in the open field during 2007- 2013. Meanwhile, the annual net return in screen net was L.E 9940 (US$ 1117) per feddan, while net return in the open field was L.E 6451(US$ 725) per feddan (Mohamed and Medany, 2015). During the past few years, the orange cropping economy has been in significant decline as the farm-gate income covers the production costs only marginally at best. Rising input costs and foreign competition have been cited frequently to be the principal causes. Direct government subvention for orange growers has been solicited actively during the past few years (Anon, 2011).

The purpose of this study is to assess the economic benefits of shaded navel orange trees with different irrigation levels. This study goes beyond the economic benefit analysis in several ways:-

- Test the effect of screen net, in comparison to the open field, on navel orange production under three irrigation levels (60, 80 and 100 %) from actual water needs;
- Monitor the climatic parameters under screen net;
- Determine the optimum water requirement that gives the highest quantity and quality of citrus fruit under screen net as well as WUE;
- Establish mathematical models for estimating some factors affecting irrigation requirements of navel orange; and
- To compare the profitability of screen net greenhouse and open-field navel orange production systems.

2. MATERIALS AND METHODS

2.1. Site description and experimental design

This investigation was carried out, at the protected cultivation experimental farm at El_Bossaily site, Behairah Governorate, Egypt (30° 35` N Latitude and 30° 36` E Longitude), during two successive seasons 2015 and 2016 on sandy texturing soil. Two navel orange fields (*Citrus sinensis* cv. Navelina), 8 years old on Volka Mariana rootstock, were chosen. The trees in the first treatment were planted under screen net greenhouse, in a 4m × 4m grid (250 trees/acre); while the second treatment trees were in the open field. The complete randomised block design was used with three replicates per treatment. Three blocks assigned to each of two main treatments, each main treatment consist of three irrigation levels (60, 80 and 100 per cent), each main treatment consisted of nine experimental plots (three irrigation levels and three replicates). Each replicate contained 15 trees (three rows and five trees in each row). The total area of sub treatment blocks were 2160 m^2 (three irrigation levels x 720 m^2). The initial shading of the net was 25 per cent, which has been gradually increased due to dust adherence. The treatments were arranged in a split plot design with three replicates (each replicate had one plant in a soil lysimeter container of 1.5 m^3 and was used to estimate the amount of water consumed within the active root zones). A piezometer tube was installed 1.5 m below the soil surface in order to monitor and record water table level. The soil pH was 6.6; reflect field capacity13.4% and permanent wilting point 6.7%.

The single span top net house style was constructed covering 4000 m^2, with 4 m height using a combination of 4" and 2" wood poles connected and anchored to the ground with 3-5 mm steel cables at a distance of 5m between poles while perpendicular supporting wires were installed every 20 m. The screen net was stretched over the wires covering the top and all sides of the house structure in order to optimise maximum wind protection.

The orange trees in all plots were irrigated and fertilised by a drip irrigation system using two lines of laterals on each row.

The reference evapotranspiration (ET_o) utilising the modified FAO "Penman" equation was used for soil properties and calculation of the irrigation intervals. The crop coefficient (Kc) was determined from the relationship between ETc and ET_o. Water flow metres were installed in each treatment to measure the amounts of irrigation water. WUE for each treatment was calculated as fruit yield divided by seasonal ETc.

Data were recorded on mean air and soil temperatures, wind speed, relative humidity and net radiation, which were recorded daily under the screen net and the open field using Campbell Scientific Ltd, CR10X automatic weather station. The climatic data was used to calculate the ET_o and ETc which was determined by using the lysimeter container.

2.2. Tree measurements

Plant peak flowering date of trees was determined. The yield was measured at the end of harvesting period according to the average of total number of fruits multiplying by the fruit average weight, fruit shape was calculated by dividing fruit length by fruit widths, the fruit lengths and widths were measured by a digital clipper, and the fruit size (volume) was estimated by the displacement method. Total soluble solids (TSS) concentration was measured with a digital temperature corrected refractometer (Mark III refractometer model No. 131499, Reicheat, USA). Titratable acidity (TA) was determined according to AOAC; the results were expressed in terms of percentage of citric acid ml^{-1} of juice. TSS: TA ratio, the relation between soluble solids and titratable acidity was calculated. Acidity of juice was measured by pH-meter (Consort pH meter P107, Belgium) Ascorbic acid (vitamin C) content was determined by endophenol method according to AOAC.

The results were statistically analysed using F-value test and the means were compared by the L.S.D at the level of 5% probability. MSTATC was the computer program that used to calculate the obtained results and statistical analysis. The benefit cost analysis (BCA), as an economic analysis tool for decision making project evaluation, was chosen as the most appropriate economic method to use. BCA is a widely used tool for comparing alternative courses of action by reference to the net benefits that they produce, and comparing a base case (no change) with the proposed option. BCA's for multiple projects can be compared to determine which project has a higher economic return relative to the others with higher BCA's indicating higher return.

3. RESULTS AND DISCUSSIONS

3.1. Effect of screen net on microclimate and water relations

3.1.1. Microclimate

The results of microclimatic conditions during this study are shown in Figure 1 including mean air temperatures, soil temperatures, wind speed, relative humidity and net radiation under screen net during the two seasons from January 2015 to December 2016. Mean air temperature and wind speed were reduced under screen net, during daily summer hot hours, meanwhile relative humidity has been increased compared to open field. Consequently, radiation was reduced under the screen net, which indicates that the soil received a fairly low amount of solar radiation as compared to the open field. Figure 1 also shows that 2015 was hotter and drier than the other one of 2016. These results were in line with those reported by Perez *et al.* (2006); Elad *et al.* (2007); Retamales *et al.* (2008) and Stamps (2008) who studied the influence of screen net upon temperatures, radiation and other microclimate parameters under different net cover and showed that the air temperature and light intensity decreased, while relative humidity increased under screen net.

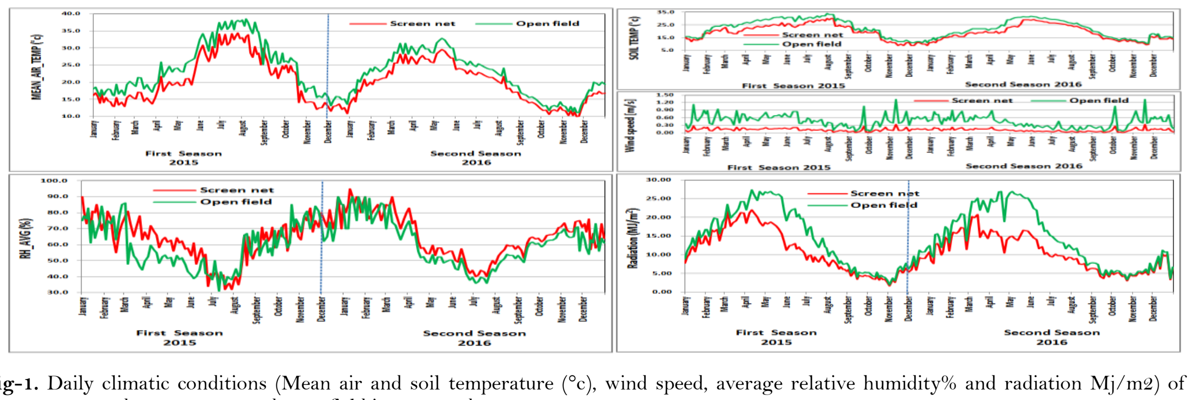

Fig-1. Daily climatic conditions (Mean air and soil temperature (°c), wind speed, average relative humidity% and radiation Mj/m2) of navel orange trees under screen net and open field in 2015 and 2016 seasons.

3.1.2. Evapotranspiration (ET_o)

The daily climatic data were used for estimating the daily reference evapotranspiration (ET_o) according to the "modified Penman" equation from January 2015 to December 2016. The data in Figure 2 presents the daily reference evapotranspiration (ET_o) during the two seasons. The total reference evapotranspiration (ET_o) values in the two seasons for the screen net and open field treatments were 423.7 and 524.5 mm, respectively. The highest values were obtained on May 21, 2015 and April 11, 2016 at 5.3 and 5.4 mm day^{-1} from the open field treatments. Meanwhile, the lowest values were 0.42 and 0.52 mm day^{-1} under screen net treatments in November 11, 2015 and December 27, 2016 respectively. The values were gradually increased with the progress in plant development during hot dry summer season. It is important to note that a high relative humidity, despite the reduction of radiation (photosynthetically active radiation), combined to lower temperature inside the nets which could decrease the atmospheric vapor pressure deficit and therefore the evapotranspiration crop demand decreased (Allen *et al*., 2006). Also, the decrease in evaporation associated with the use of nets and a significant reduction in wind speed (Elad *et al*., 2007).

3.1.3. Water requirements

Water requirements were affected by both plant development stages and climate conditions. The effect of both treatments on water requirements (Figure 2) clear that this assessment was gradually increased with the progress of the plant age till maximum was reached in June from the mid stage, and then turned to decrease slightly till the end of the growing season. It is obvious that the minimum values were found after the start of planting. This trend may be related to the continuous gradual increase in the water consumptive use with the progress of plant growth till the end of development. However, in descending order the arrangement of the water requirements values generally began with screen net, then was followed by the open field. At the same time the trees with low rate of water consumption (60%) received less water compared with the overall treatments with and without screen net. This result may be attributed to that nettings may reduce wind speeds and wind run which can affect temperatures, relative humidities, and gas concentrations resulting from reductions in air mixing (Robert, 2009). These changes can affect transpiration, photosynthesis, respiration, and other processes which reflect on water consumptive use (Doorenbos and Pruitt, 1984; Hane and Pumphrey, 1984).

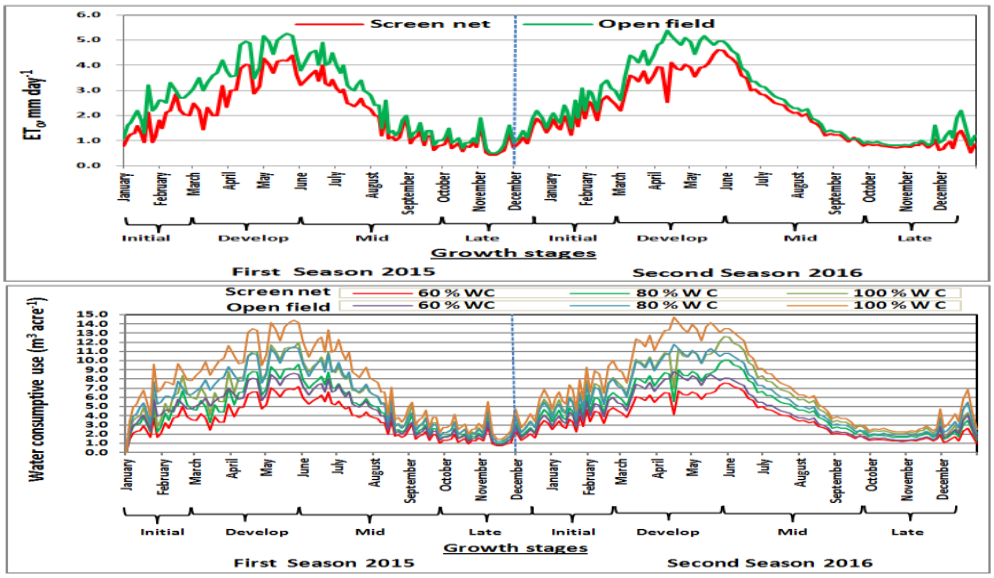

Fig-2. Daily reference evapotranspiration (ET_o, mm day^{-1}) and water consumptive use (m^3/acre) of navel orange trees under various treatments from January 2015 to December 2016.

3.1.4. Crop coefficient (Kc)

Determination of crop coefficient (Kc) value depends on planting time, stage of crop development, climatic conditions and soil moisture which is usually expressed as a function of time (days after planting). In the present investigation, the values of Kc were calculated by using actual evapotranspiration (ETc) which was measured by volumetric method (lysimeter container) under the various rate of water consumption with and without screen net that is nominated as a function of days after planting (Figure 3). The values of Kc increased gradually and reached the maximum at the development stage for the screen net. Meanwhile, this maximum was shifted 16 days later for the open field, and then both decreased gradually till the end of the growing season. Harvesting begin 35 and 25 days earlier in screen net treatment than in open field in both seasons, respectively. The screen net treatments and the Kc values were the maximum with the optimum amounts of irrigation water with the rate of 80% water needed, followed by the 60% under screen net then the open field treatment. The mid-season value is higher than initial and ending values opposite the trend of (FAO 56) as a result of under arid and semiarid regions, the trend was smooth and normal, which may be due to the effects of stomatal opening during periods of peak ET. Adverse for humid and subhumid climates where there is less stomatal control by citrus, values for Kc ini, Kc mid, and Kc end can be increased by 0.1 - 0.2 following Rogers *et al.* (1983). The values are in correspondance to Doorenbos and Pruitt (1977) and with more recent measurements. Moreover, data in the same figure represents the six order polynomial regression equations and the coefficient of determination (R^2) which describes the relation between the values of Kc and the days after planting. These relations exhibit highly significant correlations with the addition of different levels of irrigation. Alternatively, Kc for navel orange exposed to different levels of irrigation water with and without shading can be directly estimated from those mathematical models.

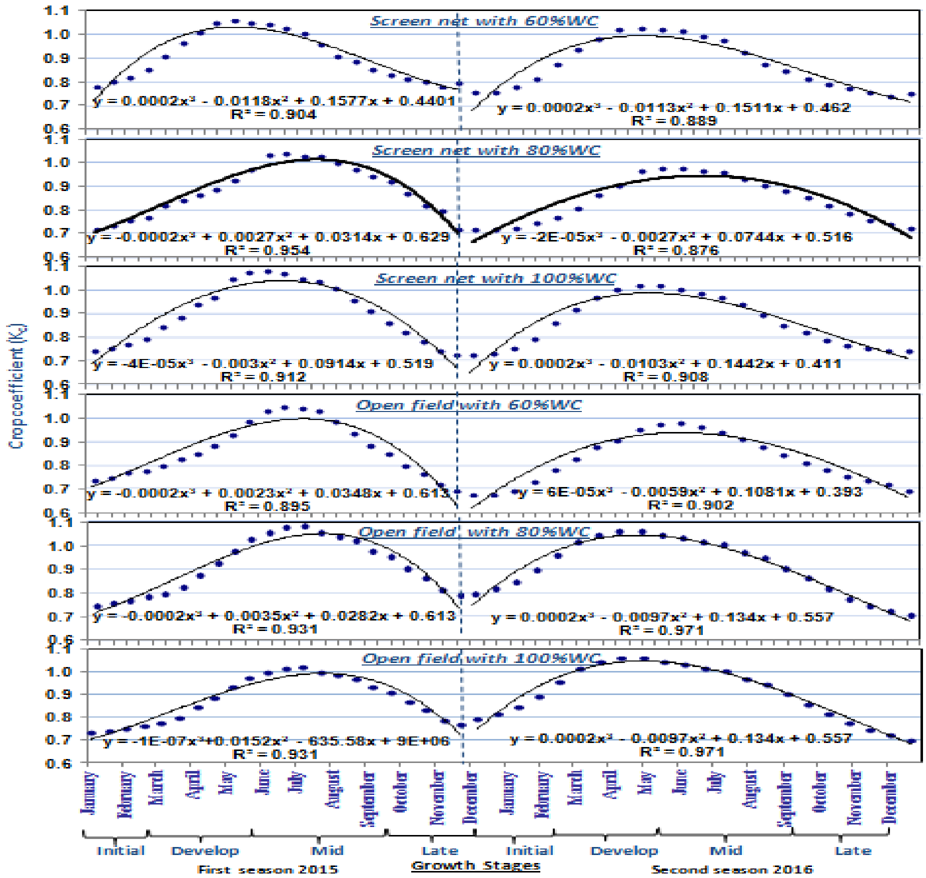

Fig-3. Crop coefficient (Kc) of navel orange trees under various treatments from January 2015 to December 2016.

3.1.5. Drainage water

Drainage water (Litre per tree) of navel orange was measured by lysimeter container and piezometer tube which indicate soil water balance and water table within the active root zone. The results in Figure 4 of drainage water pointed that the water amount under screen net lose more water in the deep percolation than the open field especially in the initial stages of growth. These results explain why shading trees perform well under lower irrigation rates (Doorenbos and Kassam, 1986; Refaie *et al.*, 2012). The daily actual water values varied with the change in climatic conditions and plant growth. At the initial stages of growth the rate of actual water use was low, which was followed by gradual increases to reach the maximum value at the end of the developmental stages. At the mid-season the rate of actual water use declined from full development up till harvest. The actual water use was decreased with the severity of soil water stress and this reduction can be attributed to the shortage of available water in the root zone, which resulted from the low amounts of added water under screen net.

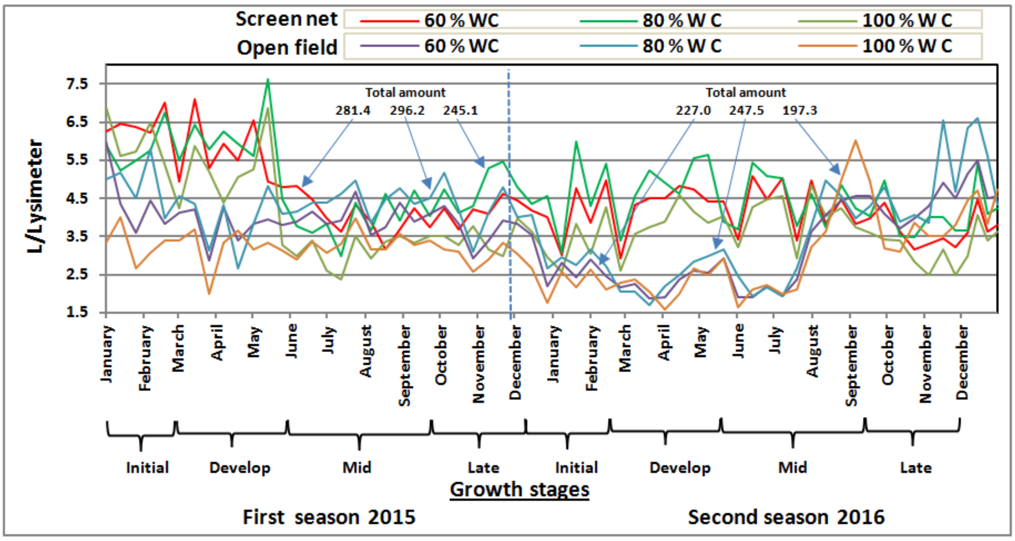

Fig-4. Drainage water (L/Lysimeter) of navel orange trees under various treatments from January 2015 to December 2016.

3.2. Effect of screen net and water consumption on plant development and fruit characteristics

The growth of navel orange trees under screen net was found fast (Table 1) representing early flowering, coming in advance in date of peak flowering by 16, 15 days and then harvest by about 25 to 35 days earlier than the open field in both seasons respectively. Such findings sustained that screen net enhanced physiological status without alteration in trees performances. Screen net greenhouse with rate of 80% water consumption gave rise to heavier fruit weight, more fruit number, longer, wider, and bigger fruit size as well as fruit uniformity than the overall other treatments (Tables 1 and 2), that enhanced internal fruit quality (Table 3) which led to have high yield and best quality of navel orange illustrated in Table 4.

3.2.1. Plant flowering and fruit development

The effects of screen net with various amounts of water consumption on the plant flowering date and fruit performance shown in Table 1. As for peak flowering date (days), number and weight of fruit, the obtained data shows that the peak of flowering date did not significantly affected by irrigation rates, but this characteristic was affected significantly by screen net. The average fruit number and weight was significantly reduced under open field compared to screen net whereas; those characteristics were significantly affected by different rate of water consumption in both seasons. Regarding the interaction between irrigation water amounts and screen net treatments in the same table, it was shown that screen net with the optimum rate of 80% from water consumption increased significantly, those characteristics of fruit number and weight over the overall water rates with and without screen net in both seasons. Meanwhile, there were no significant differences in average fruit weight characteristic between the two interactions rates of water 60 and 80% under screen net in the first season only. The screen net (regardless colour) led to diffuse light and then increase radiation use efficiency, yields (both at the plant and ecosystem level), and even be a factor affecting plant flowering and growth as well as fruit performance, especially with adjust water needed (Guenter *et al.*, 2008; Abouatalah *et al.*, 2012; Abul-Soud *et al.*, 2014).

Table-1. Effect of various irrigation levels and plant cover on plant flowering and fruit development of navel orange during 20015 and 2016 seasons.

Irrigation levels (%)		**Peak flowering date (Days)**		**Aver. fruit number**		**Aver. fruit weigh (g)**	
Plant cover		First season 2015	Second season 2016	First season 2015	Second season 2016	First season 2015	Second season 2016
60	Screen net	46.3	48.3	452.0	438.3	215.0	220.3
	Open field	61.0	64.0	310.0	301.0	205.0	208.0
	Mean	53.7	56.2	381.0	369.7	210.0	214.2
80	Screen net	46.0	48.0	469.0	446.0	218.0	236.0
	Open field	61.0	64.0	317.7	312.0	212.0	218.0
	Mean	53.5	56.0	393.3	379.0	215.0	227.0
100	Screen net	46.0	48.0	438.0	430.0	212.0	204.0
	Open field	60.7	63.7	302.0	289.7	198.0	197.7
	Mean	53.3	55.8	370.0	359.8	205.0	200.8
Mean plant cover	Screen net	46.1	48.1	453.0	438.1	215.0	220.1
	Open field	60.9	63.9	309.9	300.9	205.0	207.9
L.S.D at 5%	Irrigation levels	NS	NS	6.1	2.6	3.6	2.9
	Plant cover	1.8	1.1	2.3	1.9	1.4	1.2
	Interaction	NS	NS	6.8	3.0	4.1	3.2

3.2.2. Fruit physical characteristics

It is clear that the physical parameters of fruit (width, length, size and shape) significantly increased under the screen net conditions compared to the open field (Table 2). Also, the results indicate that there are significant differences between the water treatments in the fruit physical characteristics (width, length and size) with the superiority of the rate of 80% water consumption over the other irrigation levels. On the other hand, the results of fruit shape traits reflect that there were no significant differences between levels of water consumption in these studied characteristics. The presented results in Table 2 show the interaction effect of the studied factors on fruit physical parameters (width, length, size and shape). These parameters were significantly superiored under screen net conditions interacted with 80% irrigation level compared to other interaction treatments, except fruit shape characteristic, which was no significantly affected by such interaction. It seems that the screen net helped to reduce evapotranpiration and to keep water into the soil (Abouatalah *et al.*, 2012). Consequently, the sap flow in covered trees is lower than in exposed trees. Climate is the most important component of the climate-soil-culture complex causing differences in physical and internal fruit quality among commercial citrus production areas.

3.2.3. Fruit chemical characteristics

The parameters of internal chemical of fruit (TSS, acidity, soluble solids to acidity and vitamin C) significantly increased under the screen net conditions than the open field (Table 3). The results indicate that there are significant increases in the same parameters by using rate of 80% irrigation level compared to both rates of 60 and 100%. On the other hand, the results of interaction reflect that there were significant differences between the interaction treatments. The rate of 80% irrigation level with screen net was the highly significant one compared to other treatments among all the studied characteristics. Results obtained were matching the data gathered by Nicolas *et al.* (2005); Talamini do Amarante *et al.* (2011) and Abouatalah *et al.* (2012) who stated that increasing fruit internal quality by screen net with adjust water quantity may be due to increase in soil temperature and application of greenhouse covers; which resulted in enhancement of air and soil environment around roots of plants, and which led to increasing plant growth and increasing nutrient absorption.

Table -2. Effect of various irrigation levels and plant cover on physical characteristics of navel orange fruits during 2015 and 2016 seasons.

Irrigation levels (%)		Fruit length (cm)		Fruit width (cm)		Fruit shape		Fruit size (mm)	
Plant cover		First season 2015	Second season 2016	First season 2015	Second season 2016	First season 2015	Second season 2016	First season 2015	Second season 2016
60	Screen net	17.0	18.0	17.0	16.0	1.13	1.20	321.7	321.0
	Open field	17.7	17.0	16.7	15.0	1.06	1.06	311.7	309.7
Mean		17.3	17.5	16.8	15.5	1.09	1.13	316.7	315.3
80	Screen net	21.0	20.0	19.0	19.0	1.37	1.17	337.3	331.7
	Open field	18.0	19.0	16.0	17.0	1.13	1.02	317.3	315.0
Mean		19.5	19.5	17.5	18.0	1.25	1.09	327.3	323.3
100	Screen net	16.0	16.7	14.0	13.7	1.11	1.11	312.0	310.0
	Open field	15.3	14.0	14.3	14.0	1.07	0.97	298.3	296.0
Mean		15.7	15.3	14.2	13.8	1.09	1.04	305.2	303.0
Mean plant cover	Screen net	18.0	18.2	16.7	16.2	1.20	1.16	323.7	320.9
	Open field	17.0	16.7	15.7	15.3	1.09	1.02	309.1	306.9
L.S.D at 5%	Irrigation levels	1.8	0.8	1.8	0.8	NS	NS	3.5	2.0
	Plant cover	0.5	0.2	0.5	0.2	0.07	0.05	1.5	0.8
	Interaction	1.8	0.7	1.8	0.7	NS	NS	4.1	2.3

Table-3. Effect of various irrigation levels and plant cover on chemical characteristics of navel orange fruits during 2015 and 2016 seasons.

Irrigation levels (%)		TSS		Acidity		Soluble solids to acidity		Vitamin C	
Plant cover		First season 2015	Second season 2016	First season 2015	Second season 2016	First season 2015	Second season 2016	First season 2015	Second season 2016
60	Screen net	13.97	14.07	0.69	0.88	16.08	16.14	52.00	52.80
	Open field	13.77	15.07	0.87	0.89	15.97	17.10	51.67	53.67
Mean		13.87	14.57	0.78	0.88	16.02	16.62	51.83	53.23
80	Screen net	14.67	16.17	0.98	1.10	16.38	17.89	54.00	57.00
	Open field	13.50	14.80	0.88	0.90	15.30	16.44	51.00	54.00
Mean		14.08	15.48	0.93	1.00	15.84	17.16	52.50	55.50
100	Screen net	13.27	14.00	0.69	0.92	15.18	15.43	49.00	49.00
	Open field	12.80	13.60	0.92	0.94	13.90	14.46	44.00	48.33
Mean		13.03	13.80	0.81	0.93	14.54	14.95	46.50	48.67
Mean plant cover	Screen net	13.97	14.74	0.79	0.96	15.88	16.48	51.67	52.93
	Open field	13.36	14.49	0.89	0.91	15.06	16.00	48.89	52.00
L.S.D at 5%	Irrigation levels	0.52	0.25	0.05	0.02	0.52	0.25	1.36	1.78
	Plant cover	0.16	0.04	0.03	0.01	0.16	0.04	0.55	0.51
	Interaction	0.55	0.24	0.06	0.03	0.55	0.24	1.56	1.84

3.2.4. Yield characteristics

Table 4 showed that the yield parameters (crop yield, percentage of the marketable fruits and marketable yield) were significantly higher under screen net than the open field. Also, the same parameters of yield were significantly increased with trees exposed to rate of 80% water consumption than other rates of water treatments. At the same time, the results of yield parameters in the same table reflect that the interaction between water rates with and without screen net was significant.

The superiority still remains with the rate of 80% irrigation level under screen net over the other interaction treatments. Excessive leaf loss in the fall and in early winter will reduce accumulation of carbohydrates affecting flowering, fruit set and fruit yield. Therefore, good practices in citrus groves (shading and adjust water needed) should be adapted to minimise negative plant physiological stresses, improve tree health and performance, and enhance citrus trees to produce high yield of good fruit quality (Mongi, 2011).

Table-4. Effect of various irrigation levels and plant cover on yield characteristics of navel orange trees during 2015 and 2016 seasons.

Irrigation levels (%)		Aver. crop yield (kg/ tree)		Marketable fruits (%)		Aver. marketable yield (kg/ tree)	
Plant cover		First season 2015	Second season 2016	First season 2015	Second season 2016	First season 2015	Second season 2016
60	Screen net	96.8	84.5	86.0	87.7	83.6	84.5
	Open field	63.6	64.5	73.5	73.6	47.3	47.5
	Mean	80.2	74.5	79.8	80.7	65.5	66.0
80	Screen net	104.5	104.5	90.3	94.6	85.8	92.2
	Open field	67.0	68.5	74.1	76.1	47.1	51.3
	Mean	85.7	86.5	82.2	85.4	66.4	71.8
100	Screen net	90.9	88.2	82.7	80.2	80.4	76.2
	Open field	60.2	60.1	70.0	70.7	44.6	43.3
	Mean	75.5	74.2	76.4	75.5	62.5	59.7
Mean Plant cover	Screen net	97.4	92.4	86.3	87.5	83.3	84.3
	Open field	63.6	64.4	72.5	73.5	46.3	47.3
L.S.D at 5%	Irrigation levels	4.2	2.6	1.9	2.8	1.8	2.6
	Plant cover	1.0	1.2	0.6	1.0	0.5	1.1
	Interaction	4.2	3.2	1.9	3.2	1.8	3.0

3.2.5. Water Use Efficiency (WUE)

Data on water use efficiency are presented in Figure 5. The highest value of WUE was obtained from plants grown under the screen net with 80% irrigation level in the two seasons. Plants grown under screen net with optimum water conditions (80% irrigation level) produced 29.2 and 26.6 kg mm^{-1} fruits production per unit of water compared to the open field treatments, which produced 15.1 and 15.2 kg mm^{-1} in both seasons respectively. Such results recommend the utilisation of screen net over navel orange plantation; especially in the newly reclaimed lands to save irrigation water. In this respect some authors reported that, it is the best to integrate daily WUE corresponded to the shaded citrus and other tree crops treatments (Alarcon *et al.*, 2006; Refaie *et al.*, 2012).

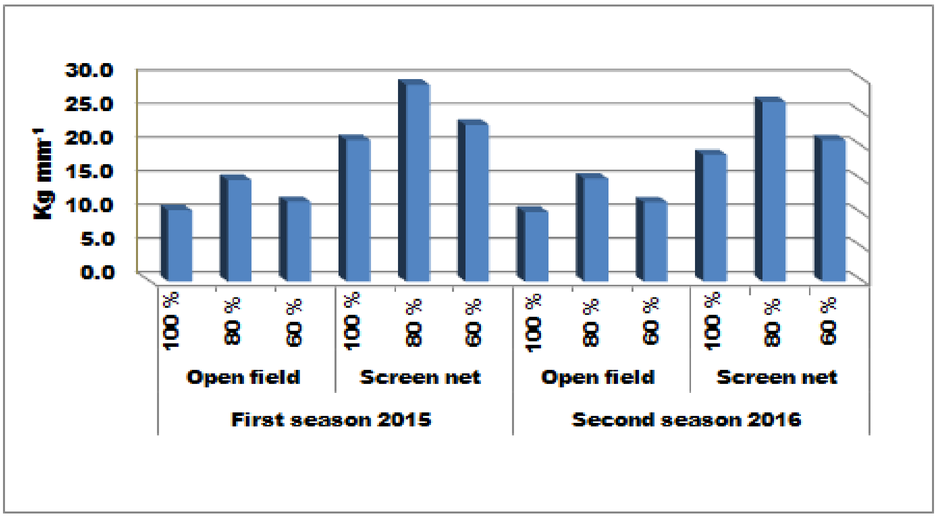

Figure-5. Water use efficiency (kg mm^{-1}) of navel orange trees under various treatments from January 2015 to December 2016.

3.2. Economic considerations

3.3.1. Total costs of production

Table 5 shows the analysis of total cost of production of navel orange due to various irrigation levels in US$, during the first season for screen net treatments. The value of fertilisation where the main cost items for all treatments (37.5%, 36.9% and 36.4 of total production costs), for the 60%, 80% and 100% irrigation levels, respectively, followed by the value of nets about 23.5%, 23.4 and 22.7% of the total production costs in 60%, 80%, 100% irrigation levels, respectively. The value of pruning and herbicides came in the third place about 6.7%, 6.6%

and 6.5% of total production costs for the 60%, 80% and 100% irrigation levels, respectively. For the open field treatments, the value of fertilisation where the main cost items for all treatments were (46.5%, 45.5% and 44.4 of total production costs), for the 60%, 80% and 100% irrigation levels, respectively, followed by the value of insecticides, herbicides and pruning with the same values about 10%, 9.7% and 9.5% of total production costs during the first season.

The results in table 5 showed that the analysis of total cost of production of navel orange due to various irrigation levels in US$, during the second season for screen net treatments. The value of fertilisation where the main cost items for all treatments (36.9%, 36.3% and 35.7 of total production costs), for the 60%, 80% and 100% irrigation levels, respectively, followed by the value of nets about 21.6%, 21.2 and 20.8% of the total costs for the 60%, 80%, 100% irrigation levels, respectively. The value of pruning came in the third place about 7.4%, 7.3% and 7.1% of total production costs for the 60%, 80% and 100% irrigation levels, respectively. For the open field treatment, the value of fertilisation where the main cost items for all treatments (46.3%, 45.2% and 44.1 of total production costs), for the 60%, 80% and 100% irrigation levels, respectively, followed by the value of pruning about 10.8%, 10.5% and 10.3% of total production cost for the 60%, 80% and 100% irrigation levels, respectively. The value of herbicides came in the third place about 10%, 9.8% and 9.6% of total production costs for the 60%, 80% and 100% irrigation levels, respectively.

Table-5. Total costs of production analysis of navel orange due to different levels of irrigation (720 m^2) during 2015 and 2016 seasons

Treatment combination	Pruning US$	Hoeing US$	Irrigation US$	Fertilisation US$	Herbicides US$	Insecticides US$	Net US$	Fruit branch support US$	Maintenance US$	others US$	T. variable costs US$
First season											
60%											
Screen net	6.3	4.7	4.5	35.0	6.3	5.3	21.9	3.1	3.1	3.1	93.3
Open field	7.5	6.6	5.3	35.0	7.5	7.5	-	2.8	-	3.1	75.3
80%											
Screen net	6.3	4.7	6.0	35.0	6.3	5.3	21.9	3.1	3.1	3.1	94.8
Open field	7.5	6.6	7.0	35.0	7.5	7.5	-	2.8	-	3.1	77.0
100%											
Screen net	6.3	4.7	7.5	35.0	6.3	5.3	21.9	3.1	3.1	3.1	96.3
Open field	7.5	6.6	8.8	35.0	7.5	7.5	-	2.8	-	3.1	78.8
Second season											
60%											
Screen net	7.5	5.6	5.3	37.5	6.9	5.3	21.9	3.8	4.7	3.1	101.5
Open field	8.8	7.8	6.0	37.5	8.1	6.6	-	3.1	-	3.1	81.0
80%											
Screen net	7.5	5.6	7.0	37.5	6.9	5.3	21.9	3.8	4.7	3.1	103.3
Open field	8.8	7.8	8.0	37.5	8.1	6.6	-	3.1	-	3.1	83.0
100%											
Screen net	7.5	5.6	8.8	37.5	6.9	5.3	21.9	3.8	4.7	3.1	105.0
Open field	8.8	7.8	10.0	37.5	8.1	6.6	-	3.1	-	3.1	85.0

3.3.2. Total return

The total return from the different treatment combinations in the first season ranged between minimum US$ 186.25 and maximum US$ 323.25 (Table 6). The highest total return US$ 323.25 was involved in screen net treatment with 80% irrigation level, and the lowest total return US$ 186.25 was involved in open field treatment with 100% irrigation level. The total return from the different treatment combinations in the second season ranged between minimum US$ 202.81 and maximum US$ 352.63 (Table 6). The highest total return US$ 352.63 was involved in screen net treatment with 80% irrigation level, and the lowest total return US$ 202.81 was involved in open field treatment with 100% irrigation level.

Table-6. Total yield, total cost of production, total return, gross margin and BCA of navel orange due to various irrigation levels during 2015 and 2016 seasons

	First season					second season				
Treatment combinations	Total yield tonne	Total cost of production US$	Total return US$	Gross margin US$	BCA	Total yield tonne	Total cost of production US$	Total return US$	Gross margin US$	BCA
60%										
Screen net	4.356	93.25	300.13	206.88	3.21	3.802	101.50	285.13	183.63	2.8
Open field	2.862	75.25	196.75	121.50	2.6	2.902	81.00	217.63	136.63	2.7
80%										
Screen net	4.702	94.75	323.25	228.50	**3.4**	4.702	103.25	352.63	249.38	**3.6**
Open field	3.015	77.00	207.31	130.31	2.7	3.082	83.00	231.13	148.13	2.8
100%										
Screen net	4.090	96.25	281.19	184.94	2.9	3.969	105.00	297.69	192.69	2.8
Open field	2.709	78.75	186.25	107.50	2.4	2.704	85.00	202.81	117.81	2.4

Farm gate price per tonne in the first season = US$ 68.75. - Farm gate price per tonne in the second season = US$ 75.

3.2.3. Gross margin

The presented results in Table 6 shows that the gross margin of the different treatment combinations in the first season ranged between minimum US$ 107.5 and maximum US$ 228.5. The highest gross margin US$ 228.5 was involved in screen net treatment with 80% irrigation level, and the lowest gross margin US$ 107.5 was involved in open field treatment with 100% irrigation level. The presented results in Table 6 shows that the gross margin of the different treatment combinations in the second season ranged between minimum US$ 117.81 and maximum US$ 249.38. The highest gross margin US$ 249.38 was involved in screen nets treatment with 80% irrigation level, and the lowest gross margin US$ 117.81 was involved in open field treatment with 100% irrigation level.

3.2.4. Benefit cost analysis

Among the different treatments, the highest BCA in the first season was recorded 3.4 in screen net with 80% irrigation level; meanwhile, the lowest BCA in the first season was recorded 2.4 in open field with 100% irrigation level (Table 6).

Among the different treatments the highest BCA in the second season was recorded 3.6 in screen net with 80% irrigation level; meanwhile, the lowest BCA in the first season was recorded 2.4 in open field with 100% irrigation level (Table 6).

4. CONCLUSION

Previous results pointed that the main limiting factors for navel orange *(Citrus Sinensis)* production are heat, wind and water stress. Therefore, the meteorological elements governing growth and flowering, development, production and quality of navel orange at a given site are basically air and soil temperatures, solar radiation, soil moisture and crop water use or evapotranspiration (ET_o). The obtained results provided a comprehensive account to recommend the application of the screen net with controlling irrigation water, as the most suitable treatments for navel orange growth, yield and fruit quality. Consequently, the obtained equations can be used to establish an easy way to predict the values of crop coefficient (Kc) at any time after planting during the same growth season and in the regions having similar climatic conditions. The cost and return analysis indicated that the highest BCA (3.4 and 3.6) were obtained from screen net with 80% irrigation level treatments in the first and second seasons respectively.

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