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EFFECT OF IRON CONCENTRATION IN THE NUTRIENT SOLUTION AND IRRIGATION SCHEDULING ON STRAWBERRY PLANTS GROWN IN HYDROPONICS

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ABSTRACT: An experiment have been conducted at the experimental site of Arid Land Agricultural Graduate Studies and Research Institute (ALARI), Ain Shams University, Qalyobia governorate during two successive seasons 2019/2020 and 2020/2021 to investigate the effect of increasing iron concentration in the nutrient solution, and irrigation scheduling on production and fruit quality of strawberry grown in hydroponics. The hydroponic system used in this experiment was the A-shape NFT (Nutrient Film Technique) system. Two factors were under investigation in this experiment; factor (A): iron concentration in the nutrient solution (3 and 6 ppm). Factor (B): irrigation scheduling (irrigation is running for 24 hours/day , irrigation is running for 15min/ hour and irrigation is running for 15 min/3 hour). Results indicated that, increase iron in the nutrient solution from 3 to 6 ppm increased early and total yield, average fruit weight, TSS % and vitamin C content in fruit. Moreover, results illustrated that the more suitable irrigation scheduling for producing strawberry grown in A-shape NFT system was 15min /h; plants irrigated for 15 min each hour recorded the highest values for early and total yield, average fruit weight, vitamin C content in fruit. Furthermore, the best interaction between the two tested factores was iron concentation 6 ppm in the nutrient solution and using irrigation scheduiling (15 min/h) for strawberry plants grown in hydroponics to achieve high yield and quality of strawberry fruits.

Key words: Strawberry, hydroponics, iron, nutrient solution,irrigation scheduling.

INTRODUCTION

Strawberry (*Fragaria* X *ananassa*) is one of the most important widely consumed small fruit in the world. Strawberry is exceedingly in demand for its taste, profitability, high yield and good quality. It has a unique, highly desirable taste and flavour and is one of the most popular fruits around the world and it is a high value source for vitamins and minerals (**Sturm *et al*., 2003**). Moreover, strawberry is one of the important export crops in Egypt which cultivated in expanded area and contributes in the national income; the cultivated area of strawberry in Egypt reached about 31897 Faddan (Faddan = 4200 m^2 = 0.42 hactear) with annual production reached about 544.945 tons (**MALR, 2019**).

Soilless culture can be identified as any method for growing plants without the use of soil, in which the nutrients absorbed by the roots are supplied via the irrigation water. Fertilizers that contain different nutrients to be supplied to the crop are dissolved with the appropriate concentration in the irrigation water and the resultant solution is referred to as “nutrient solution” (**Savvas *et al.*, 2013**). As well**, Grillas *et al.* (2001)** reported that soilless culture systems guarantee flexibility and intensification and provide high crop yield and high quality products even in areas with adverse conditions. Soilless culture is a flexible technology, sustainable and environmental production method for producing crops without need to traditional soil. Using soilless cultivation minimizes the hazard of leaching agricultural chemicals such as: fertilizers,

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pesticides or soil fumigator… etc. to the underground water (**Raja *et al.*, 2018**).

Hydroponics is a branch of soilless culture and it's identified as the art of growing plants without soil, but in water enriched with nutrients, also Nutrient Film Technique (NFT) is type of hydroponics which plants are placed in a polyethylene or PVC tube that has slits cut in the plastic for the roots to be inserted. Water mixed with nutrient solution is pumped through this tube (**Dunn, 2013**).

Nutrition management is one of the most important factors for a successful of the hydroponic cultivation (**Villora *et al.*, 1998**). Using of nutrient solution in the plant nutrition is the key for the production in soilless culture techniques (**Resh, 2000**). Iron (Fe) is an essential element for plant nutrition and it is required for various processes inside plant body such as respiration, DNA synthesis, chlorophyll biosynthesis, and photosynthesis. Furthermore, Iron has a vital role with many plant enzymes (**Kobayashi *et al.*, 2019; Jones, 2020**). In strawberry, **Lieten (2001**) illustrated that iron deficiency reduces yield and fruit size and may causes fruit abortion.

Irrigation scheduling is another factor that play a critical role in hydroponic production. **Simonne and Dukes (2009)** mentioned that poor timing and insufficient irrigation or excessive watering may affected negatively on yield and quality. Furthermore, **Smith and Baillie (2009)** reported that the development of irrigation technologies and scheduling allow to provide exact amounts of water at the right times to meet crop water requirements. **Kirnak *et al.* (2003)** showed a positive influence of proper irrigation scheduling on strawberry yield and fruit size.

For all of that the aim of this experiment was to investigate the effect of increase iron concentration in the nutrient solution, and irrigation scheduling on production and fruit quality of strawberry grown in hydroponics.

MATERIALS AND METHODS

Site and Plant Materials

The experiment was carried out at the experimental site of Arid Land Agricultural Graduate Studies and Research Institute (ALARI), Ain Shams University, Qalyobia Governorate during two successive seasons 2019/2020 and 2020/2021.

Fresh bare root strawberry *(Fragaria X ananassa)* transplants cv. Festival were used in this experiment. Transplants were transferred to their final place inside the holes of PVC tubes on the beginning of September in both seasons.

Description of A-shape NFT system

The A-shape NFT (Nutrient Film Technique) system was used in this experiment. The A-shape NFT system consisted of triangle iron frame forming about 60 degrees triangle "A-shape frame". Each side of the A-Shape frame had 4 PVC tubes (4 inch each) hold on gullies of iron fixed on the side of the frame and there is one tube fixed in the top of the A-Shape; this forms 9 cultivation PVC tubes for each A-Shape frame. The distance between tubes in each side was about 30 cm. holes were made in the PVC tubes to facilitate the cultivation of the plants in the tubes. The distances between holes in the same tube were 25cm.Plants were housed in holes and plant density was about 36 plant/m^2.

Each NFT system has a tank equipped with submersible pump deliver water and nutrient solution to the end of each PVC tube. The systems were establish on beds with slop about 0.5 – 1% to help in the flow of the nutrient solution and water inside tubes. Then the excess water and nutrient solution were collected from the other end of each tube and return it back to the catchment tank through a close irrigation system.

Nutrient Solution

The basic nutrient solution (F-1) that used in this experiment was the nutrient solution described by **El-Behairy (1994)**. Furthermore, EC was adjusted at range of 2.00–2.20 m.mhos^{-2}. Digital EC meter have been used to adjust the EC (Electrical Conductivity) to the required levels.

Treatments

Two factors have been tested in this experiment in relation to production and fruit quality of strawberry. The tested factors were as follow:

Fig. 1. Layout of the A-Shape NFT system

Table 1.Composition of the basic and the Fe-enrichment nutrient solutions

Type of the nutrient solution	Macro nutrients (ppm)					Micro nutrients (ppm)						
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Pb	Cd
F-1	200	45	350	180	50	**3.0**	1.00	0.06	0.10	0.25	0.16	0.01
F-2	200	45	350	180	50	**6.0**	1.00	0.06	0.10	0.25	0.16	0.01

F-1: Fe concentration 3 ppm in the nutrient solution. **F-2**: Fe concentration 6 ppm in the nutrient solution.

Factor (A): Iron concentration in the nutrient solution.

1. Fe concentration 3 ppm in the nutrient solution (F-1).
2. Fe concentration 6 ppm in the nutrient solution (F-2).

Factor (B): Irrigation scheduling.

1. Irrigation is running for 24 hours/day (24 h/ day).
2. Irrigation is running for 15 min/ hour (15min /h).
3. Irrigation is running for 15 min/3 hour (15 min / 3h).

Measurments

Different measurments have been recorded during the experimental time such as: number of leaves per plant, early and total yield per plant, average fruit weight, TSS% in fruits, vitamin C content in fruits, fruit acidity, iron content in leaves and (nitrogen, phosphorus, potassium) % in leaves.

Iron content in leaves was determined according to **Chapman and Pratt (1982)**. TSS% in fruits was recorded using hand refractometer. Furthermore, vitamin C content in fruits, fruit acidity, (nitrogen, phosphorus and potassium %) in leaves were determined using methods described by **AOAC (1990)**.

Experimental Design and Statistical analysis

This experiment included 6 treatments which were the combinations between 2 iron concentrations and 3 irrigation scheduling. The experiment was arranged in split plot design with three replicates. The iron concentration in the nutrient solution was arranged in the main plots, while irrigation scheduling was arranged in the sub plots. The collected data were analyzed using ANOVA statistical analysis as described by **Snedicor and Cochran (1980)** and means were compared by determining the least significant difference (LSD) at a probability level of 0.05.

RESULTS

Number of Leaves Per Plant

Data in Table 2 illustrated that increasing iron in the nutrient solution significantly increased number of leaves recorded per plant in both seasons.

For the effect of irrigation scheduling, data from first season illustrated that the highest no. of leaves recorded in 15min/h treatment followed by 24 h/day, while 15min/3h treatment recorded the lowest number of leaves. Moreover, differences among treatment were significant except differences between 24 h/day and both 15 min/ hand 15 min/3 h treatments were not significant. Similar trends were observed in the second season except that the difference between 24 h/day and15min/h was significant.

For the effect of interaction between iron concentration in the nutrient solution and irrigation scheduling, data illustrated that there were no significant differences among treatments in the first season. However, data collected from second season illustrated that the interaction between F-2 and 15 min/h (F-2+ 15 min/h) recorded the highest no. of leaves per plant, while interaction between F-1 and 15 min/3 h (F-1+15 min/3h) recorded the lowest values.

Early Yield Per Plant

Data in Table 3 indicated that increasing iron in the nutrient solution significantly increased early yield per plant in both seasons.

Regarding the effect of irrigation scheduling, data indicated that the highest value for early yield per plant was recorded in 15 min/h treatment followed by 24 h/day then1 5 min/3 h respectively in both seasons. Moreover, there were significant differences among treatments in both seasons.

Regarding the effect of interaction, data collected from first season showed that the interaction between F-2 and 15 min/h (F-2+15 min/h) recorded the highest value for early yield per plant, while interaction between F-1 and 15 min/3 h (F-1+15 min/3 h) recorded the lowest early yield values. For the second season, there were no significant differences among treatments.

Total Yield Per Plant

Data in Table 4 illustrated that increasing iron in the nutrient solution significantly increased values of total yield per plant in both seasons.

Regarding the effect of irrigation scheduling, data illustrated that plants irrigated with15min/h treatment recorded the highest yield per plant followed by 24 h/day then 15 min/3 h respectively in both seasons. Moreover, there were significant differences among treatments in both seasons.

Regarding the effect of interaction, data collected from both seasons illustrated that the highest yield was obtained by (F-2+15 min/h), while the lowest yield value was obtained by (F-1+15 min/3h).

Average Fruit Weight

Data in Table 5 illustrated that increasing iron concentration in the nutrient solution led to increase average fruit weight in both seasons.

Regarding the effect of irrigation scheduling, data collected from both seasons indicated that the highest value for average fruit weight was obtained by 15 min/h treatment followed by 24 h/day then 15 min/ 3h respectively. Moreover, there were significant differences among treatments except the difference between 24 h/day and 15min/3hwas not significant in both seasons.

Regarding the effect of interaction, there were no significant differences among interactions in the first season. However, data collected from the second season showed that the highest average fruit weight value was obtained by (F-2+ 15 min/h), while the lowest average fruit weight value was obtained by (F-1+15 min/3 h).

TSS % in Fruits

Data in Table 6 illustrated that increasing iron content in the nutrient solution led to increase TSS% in fruit, also the increase was significant in both seasons.

Concerning the effect of irrigation scheduling, data collected from both seasons indicated that the 15min/3h treatment recorded the highest TSS%, then 15 min/h treatment followed by 24 h/day respectively. Moreover, there were significant differences among treatments in both seasons.

Table 2. Effect of iron concentration and irrigation scheduling on number of leaves per plant of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24h/ day	15 min/h	15 min/3h	Mean
		1st season (2019/2020)		
F-1	12.33	13.00	11.33	**12.22**
F-2	14.33	15.33	13.00	**14.22**
mean	**13.33**	**14.17**	**12.17**	
		2nd season (2020/2021)		
F-1	12.67	13.00	12.33	**12.67**
F-2	14.33	16.00	13.67	**14.67**
mean	**13.50**	**14.50**	**13.00**	

LSD at 0.05

1st season			2nd season		
Fe c.	**Irri.**	**Fe c.*Irri.**	**Fe c.**	**Irri.**	**Fe c.*Irri.**
0.56	1.21	N.S.	1.12	0.53	2.27

Table 3. Effect of iron concentration and irrigation scheduling on early yield (g/plant) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24 h/day	15 min/h	15 min/3h	Mean
		1st season (2019/2020)		
F-1	180.34	200.27	174.69	**185.10**
F-2	218.40	221.60	196.47	**212.16**
mean	**199.37**	**210.94**	**185.58**	
		2nd season (2020/2021)		
F-1	164.59	179.46	144.36	**162.79**
F-2	196.83	215.47	166.13	**192.81**
mean	**180.70**	**197.46**	**155.24**	

LSD at 0.05

1st season			2nd season		
Fe c.	**Irri.**	**Fe c.*Irri.**	**Fe c.**	**Irri.**	**Fe c.*Irri.**
1.67	**5.18**	**21.98**	**9.14**	**14.70**	**N.S.**

Table 4. Effect of iron concentration and irrigation scheduling on total yield (g/plant) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24h/ day	15 min/h	15 min/3h	Mean
	1st season (2019/2020)			
F-1	579.94	618.10	536.77	**578.27**
F-2	687.03	721.90	575.67	**661.53**
mean	**633.48**	**670.00**	**556.22**	
	2nd season (2020/2021)			
F-1	559.26	586.07	538.70	**561.34**
F-2	654.16	725.63	618.06	**665.95**
mean	**606.1**	**655.85**	**578.36**	

LSD at 0.05

1st season Fe c.	Irri.	Fe c.*Irri.	2nd season Fe c.	Irri.	Fe c.*Irri.
47.95	**19.62**	**83.24**	**15.07**	**12.91**	**54.79**

Table 5. Effect of iron concentration and irrigation scheduling on average fruit weight (g) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24h/ day	15 min/h	15 min/3h	Mean
	1st season (2019/2020)			
F-1	17.96	19.61	16.85	**18.14**
F-2	19.90	22.83	19.33	**20.69**
mean	**18.83**	**21.22**	**18.09**	
	2nd season (2020/2021)			
F-1	17.10	20.10	16.03	**17.74**
F-2	20.29	21.42	20.24	**20.65**
mean	**18.69**	**20.76**	**18.13**	

L.S.D at 0.05

1st season Fe c.	Irri.	Fe c.*Irri.	2nd season Fe c.	Irri.	Fe c.*Irri.
1.56	**1.93**	**N.S.**	**1.63**	**0.85**	**3.62**

Table 6. Effect of iron concentration and irrigation scheduling on TSS in fruits (%) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24h/ day	15 min/h	15 min/3h	Mean
		1st season (2019/2020)		
F -1	6.45	8.00	9.10	**7.85**
F-2	8.36	8.83	10.17	**9.12**
mean	**7.93**	**8.42**	**9.64**	
		2nd season (2020/2021)		
F -1	6.79	7.63	8.82	**7.74**
F-2	8.94	9.81	10.04	**9.60**
mean	**7.87**	**8.72**	**9.43**	

LSD at 0.05

1st season			2nd season		
Fe c.	**Irri.**	**Fe c.*Irri.**	**Fe c.**	**Irri.**	**Fe c.*Irri.**
0.43	**0.29**	**1.23**	**0.75**	**0.33**	**1.40**

Concerning the effect of interaction, the highest TSS% was obtained by (F-2 +15 min/ 3 h), while the lowest TSS% was obtained by (F-1+ 24 h/ day).

Vitamin C in Fruits

The in Table 7 showed that increase iron concentration in the nutrient solution significantly increased the content of vitamin C in fruit in both seasons.

Regarding the effcet of irrigation scheduling, data illustrated that 15 min/h treatment recorded the highest vitamin C content in fruit followed by 24 h/day then15 min/3 h respectively in both seasons. Furthermore, data from both seasons indicated that there were significant differences among treatments except the difference between 24 h/day and 15 min/3h.

Regarding the effect of interaction, data collected from both seasons showed that there were no significant differences among interactions.

Fruit Acidity

Data in Table 8 showed that there was no significant difference between both treatments.

For the effect of irrigation scheduling, data collected from first season indicated that the 15 min/ 3h treatment recorded the lowest acidity value, then15min/h treatment and 24 h/day respectively. Moreover, there were significant differences among treatments. Similar trend was observed in the second season.

For the effect of interaction, data collected from both seasons indicated that there were no significant differences among interactions.

Iron Content in Leaves

Increase iron concentration in the nutrient solution significantly increased the iron content in leaves in both seasons; data was presented in Table 9.

Regarding the effect of irrigation scheduling, data collected from the first season showed that the highest iron content in leaves was obtained by 15 min/h treatment followed by 24 h/day then15 min/3 h respectively. Moreover, there were significant differences among treatments. Similar trends were observed in the second season except that the difference between 15 min/h and 24 h/day was not significant.

Regarding the effect of interaction, data collected from the first season showed that the highest iron content in leaves was obtained by (F-2+15 min/h), while the lowest iron content was obtained by (F-1+15 min/3h). Nevertheless, data in the second season showed that there were no significant differences among interactions.

Table 7. Effect of iron concentration and irrigation scheduling on vitamin C in fruits (mg/100 g fresh weight) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24 h/day	15 min/h	15 min/3 h	Mean
	1st season (2019/2020)			
F-1	80.04	86.06	79.75	**81.95**
F-2	89.08	94.78	83.20	**89.02**
mean	**84.56**	**90.42**	**81.48**	
	2nd season (2020/2021)			
F-1	73.80	80.50	70.30	**74.86**
F-2	87.91	91.03	85.87	**88.26**
mean	**80.85**	**85.76**	**78.08**	

LSD at 0.05

1st season			2nd season		
Fe c.	**Irri.**	**Fe c.*Irri.**	**Fe c.**	**Irri.**	**Fe c.*Irri.**
3.02	**4.23**	**N.S.**	**5.81**	**4.64**	**N.S.**

Table 8. Effect of iron concentration and irrigation scheduling on fruit acidity (%) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021.

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24h/ day	15 min/h	15 min/3h	Mean
	1st season (2019/2020)			
F-1	1.04	0.89	0.78	**0.90**
F-2	0.99	0.82	0.75	**0.85**
mean	**1.01**	**0.86**	**0.77**	
	2nd season (2020/2021)			
F-1	0.99	0.88	0.84	**0.90**
F-2	0.91	0.84	0.82	**0.86**
mean	**0.95**	**0.86**	**0.83**	

LSD at 0.05

1st season			2nd season		
Fe c.	**Irri.**	**Fe c.*Irri.**	**Fe c.**	**Irri.**	**Fe c.*Irri.**
N.S.	**0.06**	**N.S.**	**N.S.**	**0.02**	**N.S.**

Table 9. Effect of iron concentration and irrigation scheduling on iron content in leaves (ppm) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021.

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24h/ day	15 min/h	15 min/3h	Mean
		1st season (2019/2020)		
F-1	358.94	379.20	316.19	**351.44**
F-2	704.42	763.55	566.66	**678.21**
mean	**531.68**	**571.38**	**441.43**	
		2nd season (2020/2021)		
F-1	364.26	390.14	313.30	**355.90**
F-2	688.96	692.25	551.24	**644.15**
mean	**526.61**	**541.20**	**433.27**	

LSD at 0.05

1st season			2nd season		
Fe c.	**Irri.**	**Fe c.*Irri.**	**Fe c.**	**Irri.**	**Fe c.*Irri.**
83.87	**36.63**	**155.44**	**49.49**	**47.92**	**N.S.**

Nitrogen % in Leaves

Data in Table 10 illustrated that increase iron concentration in the nutrient solution significantly increased N% in leaves in both seasons.

Regarding the effect of irrigation scheduling, data collected from first season indicated that the highest N% in leaves was recorded by 15 min/h treatment followed by 24 h/day then 15 min/3 h respectively. Moreover, the difference between 15 min/h and 15 min/3 h was significant, while all other differences were not significant. Similar trend were observed in the second season except that all differences among treatments were significant.

Regarding the effect of interaction, there were no significant differences among interactions in both seasons.

Phosphorus % in Leaves

There was no significant difference between both iron concentrations in the nutrient solution on both seasons; data was presented in Table 11.

For the effect of the irrigation scheduling, data collected from the first season showed that 15 min/h treatment recorded the highest P% followed by 24 h/day then15min/3h respectively. Furthermore, differences among treatments were significant except the difference between 24 h/day and 15 min/3h. Data showed similar trend in the second season except that the difference between 15min/h and 15min/3h was significant, while all other differences were not significant.

Regarding the effect of interaction, there were no significant differences among interactions in both seasons.

Potassium % in Leaves

There was no significant difference between both iron concentrations in both seasons; data was illustrated in Table 12.

For the effect of the irrigation scheduling, data collected from both seasons illustrated that 15 min/h treatment recorded the highest K% followed by 24 h/day then 15 min/3 h respectively. Furthermore, differences among treatments were significant except the difference between 24 h/day and 15 min/3 h.

Regarding the effect of interaction, there were no significant differences among interactions in both seasons.

Table 10. Effect of iron concentration and irrigation scheduling on nitrogen % in leaves (N %) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24 h/day	15 min/h	15 min/3h	Mean
		1st season (2019/2020)		
F-1	2.56	2.68	2.17	**2.47**
F-2	2.70	3.03	2.50	**2.75**
mean	**2.63**	**2.86**	**2.34**	
		2nd season (2020/2021)		
F-1	2.45	2.93	2.29	**2.56**
F-2	3.17	3.25	2.67	**3.03**
mean	**2.81**	**3.09**	**2.48**	

LSD at 0.05

1st season			2nd season		
Fe c.	**Irri.**	**Fe c.*Irri.**	**Fe c.**	**Irri.**	**Fe c.*Irri.**
0.16	**0.31**	**N.S.**	**0.30**	**0.25**	**N.S.**

Table 11.Effect of iron concentration and irrigation scheduling on phosphorus% in leaves (P %) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021.

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24h/ day	15 min/h	15 min/3h	Mean
		1st season (2019/2020)		
F-1	0.380	0.400	0.307	**0.362**
F-2	0.384	0.510	0.352	**0.415**
mean	**0.382**	**0.455**	**0.329**	
		2nd season (2020/2021)		
F-1	0.363	0.373	0.322	**0.353**
F-2	0.372	0.443	0.334	**0.383**
mean	**0.368**	**0.408**	**0.328**	

LSD at 0.05

1st season			2nd season		
Fe c.	**Irri.**	**Fe c.*Irri.**	**Fe c.**	**Irri.**	**Fe c.*Irri.**
N.S.	**0.059**	**N.S.**	**N.S.**	**0.041**	**N.S.**

Table 12. Effect of iron concentration and irrigation scheduling on potassium % in leaves (K %) of strawberry grown in NFT system during seasons of 2019/2020 and 2020/2021

Fe concentration (Fe c.)	Irrigation scheduling (Irri.) 24h/ day	15 min/h	15 min/3h	Mean
		1st season (2019/2020)		
F-1	1.49	1.75	1.48	**1.57**
F-2	1.73	1.92	1.55	**1.73**
mean	**1.61**	**1.82**	**1.52**	
		2nd season (2020/2021)		
F-1	1.57	1.86	1.47	**1.63**
F-2	1.72	1.93	1.79	**1.81**
mean	**1.64**	**1.90**	**1.63**	

LSD at 0.05

1st season			2nd season		
Fe c.	**Irri.**	**Fe c.*Irri.**	**Fe c.**	**Irri.**	**Fe c.*Irri.**
N.S.	**0.18**	**N.S.**	**N.S.**	**0.11**	**N.S.**

DISCUSSION

From the above mentioned results it's clear that increase iron concentration from 3 to 6 ppm in the nutrient solution is more suitable for strawberry production in hydroponics; results illustrated that increase iron concentration increased number of leaves, early and total yield, average fruit weight, TSS % and vitamin C content in strawberry fruit. This may be a result that 3 ppm of iron in nutrient solution was not sufficient to the needs of strawberry specially iron is an essential element which plays a vital role in many processes in plants. Iron is an essential element for plant nutrition and it is required for various processes inside plant body such as respiration, DNA synthesis, chlorophyll biosynthesis, and photosynthesis. Furthermore, Iron has a vital role in many plant enzymes **(Kobayashi *et al*., 2019; Jones, 2020)**. Also, **Kochian (2000)** mentioned that iron is involved in formation of chlorophyll, plays a role in plant respiration (source of energy), formation of specific types of proteins, plays role for activation of number of enzymes such as catalase and peroxidase. Furthermore, **Almaliotis *et al.* (2002)** found that there was a significant linear relationship between iron concentration and yield in strawberry. Similarly, **Karp *et al.* (2002)** indicated that strawberry fruit quality increased with foliar Fe fertilization.

For the effect of the irrigation scheduling, results indicated that the more suitable irrigation scheduling for producing strawberry grown in A-shape NFT system was 15 min/h; plants irrigated for 15 min each hour recorded higher values for number of leaves, early and total yield, average fruit weight, vitamin C content in fruit than the other tested irrigation scheduling treatments (24 h/day and 15 min/3 h).This could ba a result to the conditions of air and water around the root in NFT tube; runing the irrigation for 15 min each hour may keep a wet condition around the root in the cultivation tube, the short period between irrigation intervalls maintain a adequate water and aeriation around root system so plants didn't suffered from excesive water and less aeriation like what happened in 24 h/day treatment, or more dry condition and less water like what happened in 15 min/3 h treatment. **Simonne and Dukes (2009)** mentioned that poor timing and insufficient irrigation or excessive watering may affected negatively on yield and quality. As will, **Serrano *et al.* (1992)** mentioned that the correct irrigation management can improve strawberry yields as strawberry plants show large responses to water stress, even if it is mild. Likewise, **Kirnak *et al.* (2003)** reported that the proper irrigation scheduling affect positively on the yield of strawberry. **Metwally *et al.* (2016)** investigated the effect of irrigation scheduling (15min each 2 hours and 15min each 3 hours) on the production and quality of strawberry grown in substrate culture on rooftops, their results indicated that irrigation scheduling affected significantly on strawberry grown in beds filled with perlite and placed on rooftop; plants that irrigated for 15min each 2 hours recorded higher yield than those irrigated for 15min each 3 hours.

Conclusion

It could be conclouded that increase iron concention up to 6 ppm in the nutrient solution was recommended for strawberry production in hydrponics. Moreover, the most suitable irrigation scheduling for strawberry production in hydroponics was run irrigation for 15min each hour per day.

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تأثير تركيز الحديد فى المحلول المغذى وجدولة الرى على نباتات الفراولة النامية فى المزارع المائية

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تم اجراء تجربة فى موقع التجارب التابع لمعهد الدراسات العليا والبحوث للزراعة فى المناطق القاحلة – جامعة عين شمس، محافظة القليوبية وذلك خلال موسمى 2020/2019 و 2021/2020 لدراسة تأثير زيادة تركيز الحديد فى المحلول المغذى وجدولة الرى على انتاجية وجودة الفراولة النامية فى المزارع المائية. نظام المزارع المائية الذى تم استخدامه فى هذه التجربة كان نظام الفيلم الضحل المغذى (A-shape NFT). تم اختبار عاملين فى تلك التجربة، العامل الاول كان تركيز الحديد فى المحلول المغذى (تم اختبار تركيزان من الحديد: 3جزء فى المليون - 6 جزء فى المليون)، أما العامل الثانى فكان جدولة الرى (الرى يعمل باستمرار لمدة 24 ساعة فى اليوم- الرى يعمل لمدة 15 دقيقة كل ساعة- الرى يعمل لمدة 15 دقيقة كل 3 ساعات). وقد اوضحت النتائج إلى ان زيادة تركيز الحديد فى المحلول المغذى من 3 إلى 6 جزء فى المليون أدت الى زيادة المحصول المبكر والكلى، أيضاً زاد متوسط وزن الثمرة، النسبة المئوية للمواد الصلبة الذائبة الكلية فى الثمار ومحتوى الثمار من فيتامين ج. وعلاوة على ذلك، أوضحت النتائج أن جدولة الرى الأنسب لإنتاج الفراولة المزروعة في نظام (A-shape NFT) كانت تشغيل الرى لمدة 15 دقيقة كل ساعة، حيث سجلت النباتات المروية لمدة 15 دقيقة كل ساعة أعلى القيم لكل من المحصول المبكر والكلى، متوسط وزن الثمرة، محتوى الثمار من فيتامين ج. وكان أفضل تفاعل بين العاملين المختبرين هو استخدام تركيز الحديد 6 جزء في المليون في محلول المغذيات واستخدام جدولة الرى (15 دقيقة/ساعة) وذلك لتحقيق إنتاجية وجودة عالية للثمار من نباتات الفراولة المزروعة في المزارع المائية.

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