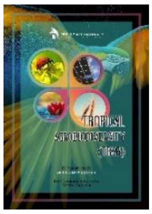
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2716-7046 (Online)
CODEN: TARGCA

Tropical Agrobiodiversity (TRAB)

DOI: http://doi.org/10.26480/trab.02.2024.62.72



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RESEARCH ARTICLE

AGRONOMIC AND ECONOMIC STUDIES OF LETTUCE PRODUCTION UNDER HYDROPONIC SYSTEMS

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ARTICLE DETAILS

Article History:

Received 24 January 2024
Revised 28 February 2024
Accepted 02 April 2024
Available online 02 May 2024

ABSTRACT

This study was conducted at the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Giza, Egypt, during two winter seasons of 2022 and 2023. To investigate the efficiency of two hydroponic systems (flat nutrient film technique "F-NFT" and deep water culture "DWC") under three nutrient solution concentrations (1.2, 1.5 and 1.8 dSm^{-1}), three number of irrigation times: (24, 36 and 48 per day) and interaction of them on growth and yield of lettuce. Treatments were arranged in a split split plot design with three replicates. Measurements were i.e., number of leaves, plant fresh weight, total yield (Kg/m^2), N, P, K and nitrate contents in leaves, chlorophyll reading, water and power use efficiency/m^2 and economic study. The results indicated that using F-NFT, solution concentration 1.8 dSm^{-1} and 48 irrigation times per day provided the highest values for all tested parameters more than other treatments. . While, from the economic study illustrated that the cultivation of lettuce in the F-NFT system, using a nutrient solution concentration of 1.5 dSm−1 and 48 irrigation times per day gain the highest net profit under a greenhouse covered by netting during the winter season.

KEYWORDS

Lettuce, Hydroponic culture, nutrient solution concentration, number of irrigation times per day, economic study.

1. INTRODUCTION

Hydroponics is a technology for growing plants in nutrient solutions without soil (Jensen, 1999). There are many different types of hydroponic systems based on how nutrient solution interacts with plant roots, root aeration, and plant support such as nutrient film technique (NFT), deep water culture (DWC), deep flow technique (DFT), and aeroponic system. In the nutrient film technique (NFT) plant roots grow partially immersed in the nutrient solution while in the deep water culture (DWC) plant roots grow completely immersed (Savvas et al., 2013). Additionally, reported that in hydroponic culture the nutrient solution is cycled constantly or intermittently and the major use of intermittent flow is to regulate plant development while also saving electricity and minimizing wear on pumps (Graves and Hurd, 1983). Hydroponics technology provides growing environment-friendly fresh vegetables more intensively to achieve high quality and yield through accurate management of nutrient composition, pH, electrical conductivity (EC) and dissolved O_2 concentration of the nutrient solution (Levine and Mattson, 2021). EC management of nutrient solutions in hydroponic systems is one of the most important controllable practices affecting the quality of leafy vegetables (Cooper, 1988). Unsuitable nutrient management, such as using a nutrient solution at a concentration that is too high or too low, or an imbalanced ion composition, could prevent plants from growing due to toxicity or nutrient-induced insufficiency resulting in negative effects on yield (Chrysargyris et al., 2021). The optimal EC level for most hydroponic crops is between 1.5 and 3.5 dS m^{-1}, but this range depends on crop type, phonological stage and climatic conditions, when, the optimum lettuce nutrient concentration is ranged between 1.2 to 1.8 dS m^{-1} (Sharma et al., 2018). Nutrient solution concentrations above optimal levels lead to nitrate accumulation and decreased photosynthesis while, decreasing the concentration of the nutrient solution from the optimal limits leads to a shortage in the supply of some elements in an insufficient which results in a decrease in productivity which, prevents nutrient depletion in the root zone and raises the concentration of dissolved oxygen in the solution (Lara et al., 2011; Lenni et al., 2020; Samarakoon et al., 2006; Yang et al., 2021).

In hydroponics, the irrigation scheduled process is fully automated to control the supply of water, nutrients and oxygen in accordance with the needs of plants. Irrigation management generally considers the frequency of irrigation (number applied of irrigation per day or week) and the intervals (durations) of each irrigation (Schröder and Lieth, 2002). Also, reported that irrigation frequency is a necessary process to maintain the flow of nutrients and water to the roots, which directly affects nutrient and water uptake and plant growth (De Swaef et al., 2011). To mentioned that in the commercial nutrient film technique (NFT) it is common to adopt a nutrient solution recirculation frequency of 0.25h (Alide et al., 2017).

On the other way, lettuce is a cool season crop with great economic value because of its yield potential. It is widely cultivated all over the world, especially in temperate and subtropical countries (Kumar et al., 2010). The cultivation of lettuce (*Lactuca sativa* L.) has been studied in several hydroponic systems, particularly water culture and nutrient film technique (Safaei et al., 2015). The main challenge of lettuce production is to determine the best hydroponic system that achieves the highest quality and quantity of yield in greenhouse, with optimal management of water and nutrients, which helps reduce environmental impacts (Spehia et al., 2018).

This experiment aimed to determine the suitable hydroponic system, concentration of the nutrient solution and number of irrigation times per day to achieve the highest yield and economic return of lettuce crop.

2. MATERIALS AND METHODS

This experiment was carried out at the experimental station of the Central

Laboratory of Agricultural Climate (CLAC), Agricultural Research Centre (ARC), Ministry of Agriculture and Land Reclamation, Egypt, in a greenhouse (9 m x 40 m) covered by white net through two winter's seasons 2022 and 2023.

2.1 Plant Material

Lettuce (*Lactuca sativus* L.) cv. seeds of an Othilie-RZF1 hybrid (Batavia green lettuce) were sown in foam trays during the first week of September in both seasons 2022 and 2023. After the fourth true leaf stage, one seedling was planted in plastic net cups (size 5 cm) filled with substrate mixtures of perlite and peat moss (1:1 v/v). Seedlings were transplanted into the two hydroponic systems in the first week of October. Lettuce was harvested after 35 days from transplanting.

2.2 Hydroponic Systems

2.2.1 Flat Nutrient Film Technique (F-NFT).

This system consists of a three flat iron frames with flat partial dimensions of 100 cm in length and 60 cm in height. Five plastic tubes UPVC with a diameter of 4 inches and a length of 3 meters are installed on the flat part of the three iron frames. Holes were made in the upper part of the tubes with kept 20 cm as a distance between holes. After that, the plastic net cups and the seedling are placed inside the holes. A tank containing a nutrient solution with a capacity of 120 liters and a submersible pump (40 watts) to pump the nutrient solution to the end of the planting tubes, then the drainage returns to the tank by gravity.

2.2.2 Deep Water Culture (DWC).

A simple construction basin (3m length x 0.6m width x 0.3m depth) was established by blocks and cement on a concrete base and covered from the inside by a black polyethylene sheet (1mm). The basin is filled with water up to 25 cm from bottom this led to save water volume equal 0.45 m^3. Holes were punched in polystyrene foam sheets (60 cm x 1.2 m) with kept 20 cm as a distance between holes, which, put inside it plastic net cups with lettuce plants. The foam panels cover the water's surface. A pump (40 watts) was installed inside to stir the nutrient solution and increase its oxygen content. There were 20 plants per square meter.

2.3 Nutrient Solution

The nutrient solution used in this experiment according to Table (1) (El Behairy, 1994).

Table 1: The Chemical Components of Nutrient Solution.

Chemical nutrient solution	Macronutrients (ppm)					Micronutrients (ppm)					
	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B	Mo
	200	70	300	190	50	5.0	1.0	0.039	0.044	0.17	0.1

2.4 Treatments

Three factors were tested in this study i.e., (A) two hydroponic systems, (B) three concentrations of the nutrient solution and (C) three number of irrigation times per day as follow:

Factor (A): Hydroponic systems

I. Flat nutrient film technique (F-NFT)

II. Deep water culture (DWC).

Factor (B): Nutrient solution concentration

I. 1.2 dSm^{-1}

II. 15 dSm^{-1}

III. 1.8 dSm^{-1}

Factor (C): Number of irrigation times per day

I. 48 irrigation times per day as (15 minutes on,15 minutes off)

II. 32 irrigation times per day as (15 minutes on, 30 minutes off)

III. 24 irrigation times per day as (15 minutes on, 45 minutes off)

2.5 Measurements.

All measurements have been recorded after 35 days from transplanting (harvesting time) as follows:

2.5.1 Vegetative Growth and Yield Characteristics.

Five lettuce plants were taken as samples from each plot (3m^2) to determine growth parameters such as number of leaves, plant fresh weight and total yield (Kg) per m^2.

2.5.2 Chlorophyll Reading (SPD)

Total chlorophyll reading was measured using a Minolta chlorophyll meter (Spad-501).

2.5.3 The Chemical Analysis

The elemental lettuce leaves contents N, P and K (%) were determined. Three plants were dried at 70 C^0 in an air-forced oven for 48 h. Dried samples were digested in a mixture of H2SO4 and HCl according to (Allen, 1974). Nitrogen, Phosphorus and Potassium contents were determined using methods described whereas, nitrate was measured by using a rapid method of (Singh, 1988; FAO, 2008).

2.5.4 Water Use Efficiency (WUE) Per M^2

Water use efficiency of each treatment was calculated according as follows: The ratio of crop yield (Y) per m^2 to the total amount of irrigation water used per m^2 during the growing season to (FAO, 1982).

WUE per m^2 (kg/m^3) = Y per m^2 (kg) / IR per m^2 (m^3).

2.5.5 Power use Efficiency Per m^2 (PUE)

The power use efficiency of treatments was calculated according to as follows: The ratio of crop yield (Y) per m^2 to the total amount of power used per m^2 for the growing season (Abul-Soud et al., 2019).

Power use per m^2 = pump power (Kilowatt) **x** operation hours per day **x** No. of days per season

PUE per m^2 (Kg / Kilowatt) = yield per m^2 (Kg) / power use per m^2 (Kilowatt)

2.5.6 Economic Study

The high costs of establishing a hydroponic systems are considered an obstacle to their spread in Egypt. As a result, it is necessary to choose a suitable system and manage it well in order to increase net profit under Egyptian conditions. Moreover, economic assessment of lettuce productivity was calculated as a two winter seasons average on the basis that the system area is six square meters (standard unit) and the possibility of producing the lettuce throughout the winter season at a rate of 4 cycles production under net greenhouse, through estimating investment costs, production costs, and marketing prices according to the Egyptian market.

The total investment cost for system 6 m^2 = total construction costs for system 6 m^2 + total operation for system 6 m^2 (seedling + irrigation + chemicals + electricity + others).

Total return for system 6 m^2 = total yield for system 6 m^2 x marketing price per Kg

The net profit for the system 6 m^2 = total return – total investment cost.

2.7 Experimental Design

The experiment was arranged in a split split-plot design with three replicates. The main plot was the hydroponic system, the sub-plot was the nutrient solution concentration and the sub-sub plot was the number irrigation.

2.7 Statistical Analysis

According to data were statistically analyzed using the analysis of variance method one-way ANOVA with SAS package software version 6 (SAS, 2005). Dunkun's test was used to compare among means.

3. Results

3.1 Vegetative Growth Parameters and Total Yield

Results in Table (2) showed that the highest number of leaves, plant fresh weight and yield per meter square were obtained by using the flat nutrient film technique (F-NFT) compared to deep water cultivation (DWC) significantly. Also, raising the concentration of the nutrient solution from 1.2 dSm^{-1} to 1.8 dSm^{-1} lead to an increase in vegetative growth and yield/m^2. On the other hand, increasing the number of irrigation times up to 48 per day recorded the highest vegetative growth and total yield per m^2, while, 24 irrigation times per day gave the lowest vegetative growth and yield per m^2.

Concerning the effect of first-order interactions on vegetative growth and yield measurements of lettuce plants is illustrated in Table (3). The interaction between hydroponic systems and nutrient solution concentration indicated that the highest vegetative growth and yield per square meter were recorded by using the (F-NFT) with a nutrient solution concentration of 1.8 dSm^{-1} followed by 1.5 dSm^{-1} without any significant difference between them in the number of leaves, while, there was a significant difference in plant fresh weight and yield per meter square. On the contrary, (DWC) with a nutrient solution concentration of 1.2 dSm^{-1} gives the lowest value of vegetative growth parameter and yield/m^2.

The interaction between hydroponic systems and number of irrigation times per day indicated that the (F-NFT) combined with either 48 irrigations times per day produced the highest vegetative growth parameters and yield/m^2 significantly than other treatments. While, the lowest vegetative growth parameters and yield/m^2 were obtained with (DWC) + number of irrigation times 24 per day.

As for the interaction between nutrient solution concentration and number of irrigation times per day, noticed that, applied a concentration of 1.8 dSm^{-1} followed by 1.5 dSm^{-1} with irrigation times 48 per day gave the highest vegetative growth parameters and yield/m^2 without significant difference. While, applying a nutrient solution concentration of 1.2 dSm^{-1} with 24 irrigation times per day recorded the lowest vegetative growth parameters and yield/m^2.

Table 2: Effect of hydroponic systems, nutrient solution concentrations and number of irrigation times per day on the number of leaves, plant fresh weight (g) and total yield (Kg/m^2) in lettuce plants during 2022-2023 seasons.

Treatments	First season			Second season		
	Number of leaves	Plant fresh weight	Yield	Number of leaves	Plant fresh weight	Yield
Hydroponic systems						
F-NFT	36.4 A	365 A	9.12 A	35.0 A	384 A	9.61 A
DWC	32.8 B	340 B	8.50 B	31.8 B	360 B	8.99 B
Nutrient solution concentrations (dSm^{-1})						
1.2 dSm^{-1}	32.5 C	278 C	6.96 C	31.5 C	291 C	7.28 C
1.5 dSm^{-1}	35.2 B	375 B	9.36 B	33.9 B	392 B	9.79 B
1.8 dSm^{-1}	36.0 A	404 A	10.11 A	34.9 A	433 A	10.83 A
Number of irrigation times per day						
24 per day	31.3 C	291 C	7.29 C	29.8 C	306 C	7.65 C
32 per day	34.8 B	353 B	8.84 B	33.6 B	370 B	9.25 B
48 per day	37.6 A	412 A	10.31 A	36.8 A	440 A	11.01 A

Table 3: Effect of first-order interaction between hydroponic systems, nutrient solution concentrations and number of irrigation times per day on the number of leaves, plant fresh (g) and yield (Kg/m^2) in lettuce plant during 2022-2023 seasons.

Treatment combination		First season			Second season		
		Number of leaves	Plant fresh weight	Yield	Number of leaves	Plant fresh weight	Yield
Hydroponic systems * Nutrient solution concentrations (dSm^{-1})							
F-NFT	1.2 dSm^{-1}	35.0 b	283 d	7.06 d	33.7 b	294 d	7.35 d
	1.5 dSm^{-1}	36.9 a	384 b	9.59 b	35.5 a	403 b	10.08 b
	1.8 dSm^{-1}	37.1 a	429 a	10.72 a	35.9 a	456 a	11.40 a
DWC	1.2 dSm^{-1}	30.0 c	274 d	6.86 d	29.2 d	289 d	7.21 d
	1.5 dSm^{-1}	33.5 b	366 c	9.14 c	32.3 c	380 c	9.50 c
	1.8 dSm^{-1}	34.8 b	380 bc	9.50 bc	33.9 b	410 b	10.26 b
Hydroponic systems * Number of irrigation times per day							
F-NFT	24 per day	32.1 de	303 e	7.57 d	30.6 d	316 e	7.90 e
	32 per day	37.3 b	370 c	9.25 b	35.3 b	387 c	9.68 c
	48 per day	39.7 a	422 a	10.55 a	39.2 a	450 a	11.26 a
DWC	24 per day	30.5 e	280 f	5.60 f	28.9 e	296 f	7.40 f
	32 per day	32.3 d	337 d	6.73 e	32.0 c	353 d	8.82 d
	48 per day	35.5 c	403 b	8.06 c	34.4 b	430 b	10.75 b
Nutrient solution concentrations (dSm^{-1}) * Number of irrigation times per day							
1.2 dSm^{-1}	24 per day	29.5 e	237 g	5.93 g	28.1 e	248 g	6.19 g
	32 per day	32.6 d	273 f	6.84 f	31.7 d	282 f	7.06 f
	48 per day	35.4 c	325 d	8.12 d	34.6 bc	344 d	8.61 d
1.5 dSm^{-1}	24 per day	32.0 d	306 e	7.64 e	30.8 d	319 e	7.98 e
	32 per day	35.1 c	363 c	9.09 c	33.4 c	372 c	9.31 c
	48 per day	38.6 a	454 a	11.36 a	37.4 a	483 a	12.09 a
1.8 dSm^{-1}	24 per day	32.4 d	331 d	8.29 d	30.4 d	351 d	8.78 d
	32 per day	36.7 b	423 b	10.58 b	35.8 b	455 b	11.38 b
	48 per day	38.8 a	458 a	11.45 a	38.4 a	493 a	12.33 a

Regarding to the effect of second-order interaction among hydroponic systems, nutrient solution concentration and irrigation number per day on vegetative growth and yield measurements of lettuce plants shown in Table (4). The highest values were obtained with the combination of the (F-NFT) system + nutrient solution concentration of 1.8 dSm^{-1} or 1.5 dSm^{-1} + irrigation number 48 per day. On the other hand, the lowest value was recorded in (DWC) + nutrient solution concentration of 1.2 dSm^{-1} + irrigation number 24 per day. These results held true in both growing seasons.

3.2 Chlorophyll reading (SPD) and nitrate content (ppm).

Presented data in (Figures 1 and 2) reflected the effect of hydroponic system, nutrient solution concentration and number of irrigation times per day on chlorophyll reading (SPD) and nitrate content (ppm). Data revealed that the (F-NFT) gave higher chlorophyll reading and nitrate content more than (DWC) system. Furthermore, raising the concentration of the nutrient solution from 1.2 dSm^{-1} to 1.8 dSm^{-1} led to an increase in chlorophyll reading and nitrate content. In addition, the highest value of chlorophyll reading and nitrate content were recorded with number of irrigation times 48 per day.

The effect of first-order interaction on the chlorophyll reading and nitrate content (ppm) in lettuce leaves presented in Table (5). The interaction between hydroponic systems and nutrient solution concentrations obtained that the highest chlorophyll reading and nitrate content (ppm) observed with (F-NFT) + nutrient solution concentration 1.8 dSm^{-1}. While, the lowest value was recorded in (DWC) with concentration 1.2 dSm^{-1} from nutrient solution.

Table 4: Effect of second-order interaction among hydroponic systems, nutrient solution concentrations and number of irrigation times per day on the number of leaves, plant fresh (g) and yield (Kg/m²) in lettuce plant during 2022-2023 seasons.

Treatment combination			First season			Second season		
			Number of leaves	Plant fresh weight	Yield	Number of leaves	Plant fresh weight	Yield
Hydroponic systems * Nutrient solution concentrations (dSm^{-1}) * Number of irrigation times per day								
F-NFT	1.2 dSm^{-1}	24 per day	31.2 ef	245 h	6.13 h	29.8 fg	256 l	6.40 l
		32 per day	36.0 cd	276 g	6.89 g	34.2 de	285 k	7.11 k
		48 per day	37.9 bc	327 f	8.17 f	37.2 bc	342 hi	8.55 hi
	1.5 dSm^{-1}	24 per day	32.7 e	307 f	7.67 f	31.8 ef	319 j	7.98 j
		32 per day	37.9 bc	377 cd	9.43 cd	35.0 cd	389 f	9.71 f
		48 per day	40.1a	467 a	11.67 a	39.6 ab	502 ab	12.55 ab
	1.8 dSm^{-1}	24 per day	32.3 e	356 de	8.90 de	30.2 fg	372 fg	9.31 fg
		32 per day	38.1 b	458 ab	11.45 ab	36.6 cd	488 bc	12.20 bc
		48 per day	41.0 a	472 a	11.80 a	40.8 a	507 a	12.68 a
DWC	1.2 dSm^{-1}	24 per day	27.7 g	229 h	5.73 h	26.4 h	239 l	5.99 l
		32 per day	29.3 fg	271 g	6.78 g	29.2 g	280 k	7.00 k
		48 per day	32.9 e	323 f	8.07 f	32.0 ef	346 hi	8.66 hi
	1.5 dSm^{-1}	24 per day	31.2 ef	305 f	7.62 f	29.8 fg	319 j	7.98 j
		32 per day	32.3 e	350 e	8.75 e	31.8 ef	356 gh	8.90 gh
		48 per day	37.1 bcd	442 b	11.05 b	35.2 cd	465 d	11.62 d
	1.8 dSm^{-1}	24 per day	32.5 e	307 f	7.67 f	30.6 fg	330 ij	8.24 ij
		32 per day	35.3 d	389 c	9.72 c	35.0 cd	422 e	10.56 e
		48 per day	36.6 bcd	444 a	11.10 b	36.0 cd	479 cd	11.97 cd

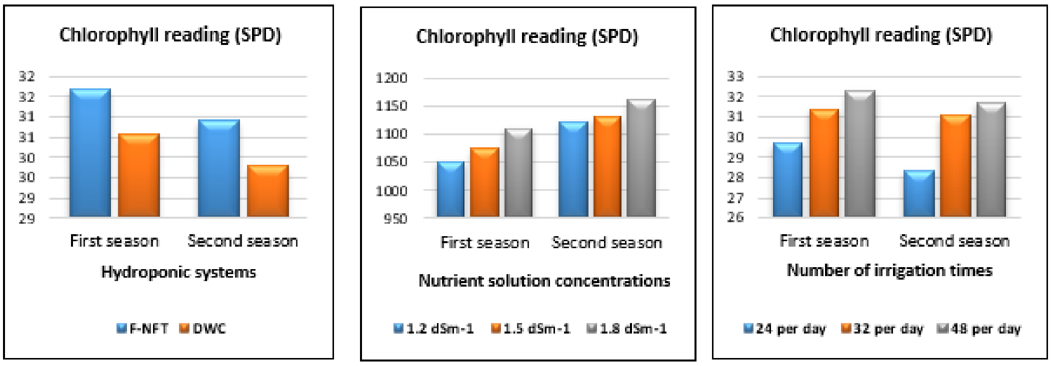

Figure 1: Effect of hydroponic systems, nutrient solution concentrations and number of irrigation times per day on chlorophyll reading (SPD) in lettuce leaves during 2022-2023 seasons

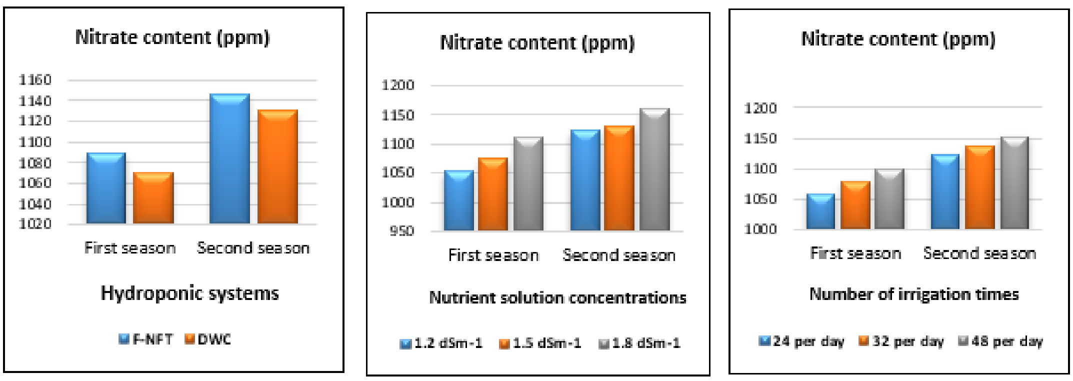

Figure 2: Effect of hydroponic systems, nutrient solution concentrations and number of irrigation times per day on nitrate content (ppm) in lettuce leaves during 2022-2023 seasons

The interaction between hydroponic systems and number of irrigation times per day, data showed that irrigation of the plants by 48 times/day and by 32 times/day in the flat nutrient film technique (F-NFT) gave the highest chlorophyll reading and nitrate content without significant difference between them. While, irrigation 24 times per day in a deep water culture (DWC) recorded the lowest value.

The interaction between nutrient solution concentration and number of irrigation per day, presented that irrigation 48 per day combined with a nutrient solution concentration 1.8 dSm^{-1} followed by daily number of irrigation 32 + nutrient solution concentration 1.8 dSm^{-1} gave the highest chlorophyll reading without significant difference between them. While, applied number of irrigation by 48 per day with a nutrient solution concentration 1.8 dSm^{-1} increased nitrate content. The lowest values were obtained by irrigation by 24 per day combined with a nutrient solution concentration 1.2 dSm^{-1}.

Table 5: Effect of first-order interaction between hydroponic systems, nutrient solution concentrations and number of irrigation times per day on chlorophyll reading (SPD) and nitrate content (ppm) in lettuce plant during 2022-2023 season.

Treatment combination		First season		Second season	
		chlorophyll reading	Nitrate content	chlorophyll reading	Nitrate content
Hydroponic systems * Nutrient solution concentrations (dSm^{-1})					
F-NFT	1.2 dSm^{-1}	28.5 e	1061 cd	27.3 d	1126 cd
	1.5 dSm^{-1}	31.1 c	1078 bc	30.3 c	1136 bc
	1.8 dSm^{-1}	35.5 a	1126 a	35.1 a	1176 a
DWC	1.2 dSm^{-1}	28.3 e	1043 d	27.1 d	1117 d
	1.5 dSm^{-1}	29.9 d	1071 bcd	29.2 c	1127 cd
	1.8 dSm^{-1}	33.5 b	1095 b	33.1 b	1145 b
Hydroponic systems * number of irrigation times per day					
F-NFT	24 per day	29.9 c	1071 bc	28.6 c	1123 c
	32 per day	32.4 ab	1089 ab	32.1 a	1152 ab
	48 per day	32.9 a	1105 a	32.0 a	1163 a
DWC	24 per day	29.5 c	1047 d	28.0 c	1123 c
	32 per day	30.4 c	1068 cd	30.0 b	1124 c
	48 per day	31.7 b	1093 a	31.4 a	1142 b
Nutrient solution concentrations (dSm^{-1}) * number of irrigation times per day					
1.2 dSm^{-1}	24 per day	27.7 f	1029 d	26.3 d	1109 d
	32 per day	28.5 ef	1057 cd	27.8 c	1124 cd
	48 per day	28.9 ef	1070 c	27.6 cd	1132 c
1.5 dSm^{-1}	24 per day	29.4 de	1064 cd	27.7 cd	1126 cd
	32 per day	30.4 cd	1068 c	30.1 b	1127 cd
	48 per day	31.6 bc	1090 bc	31.4 b	1140 c
1.8 dSm^{-1}	24 per day	31.9 b	1084 bc	31.0 b	1134 c
	32 per day	35.2 a	1111 ab	35.3 a	1162 b
	48 per day	36.4 a	1137 a	36.1 a	1186 a

Concerning the effect of second-order interaction among hydroponic systems, nutrient solution concentrations and number of irrigation times per day on chlorophyll reading and nitrate content of lettuce leaves shown in (Table, 6). Applied flat nutrient film technique (F-NFT) + nutrient solution concentration 1.8 dSm^{-1} + number of irrigation times 48 and 32 per day recorded the highest chlorophyll reading and nitrate content without significant difference between them. On the other hand, the combination of deep water culture (DWC), nutrient solution concentration 1.2 dSm^{-1}, and number of irrigation 24 times per day gave the lowest value.

3.3 N, P and K content (%).

Illustrated data in (Table, 7) indicated the effect of hydroponic systems, nutrient solution concentrations and number of irrigation times per day on N, P and K (%) contents in lettuce leaves. Data obtained that the flat nutrient film technique (F-NFT) recorded the higher values of N, P and K contents compared with deep water system. Also, plants grown in nutrient solution concentration 1.8 dSm^{-1} had higher N, P and K contents, when, the lowest N, P and K contents were found in nutrient solution concentration 1.2 dSm^{-1}. In addition, the highest N, P and K contents in lettuce plants were recorded with number of irrigation times 48 per day, while, the lowest value was obtained in irrigation by 24 times per day.

Concerning the effect of first-order interactions on contents of N, P, K (%) in lettuce leaves presented in Table (8). The interaction between hydroponic systems and nutrient solution concentrations, reflected that the highest N, P and K contents were obtained when plants grown in a flat nutrient film technique system (F-NFT) and received nutrient solution concentration 1.8 dSm^{-1} followed by deep water culture system (DWC) with nutrient solution concentration 1.8 dSm^{-1}. While, the lowest N, P and K contents were found in a deep water culture (DWC) with a nutrient solution concentration 1.2 dSm^{-1}.

Table 7: Effect of hydroponic systems, nutrient solution concentration and number of irrigation times per day on contents of N, P and K (%) in lettuce leaves during 2022-2023 seasons.

Treatment combination			First season		Second season	
			chlorophyll reading (SPD)	Nitrate content (ppm)	chlorophyll reading (SPD)	Nitrate content (ppm)
Hydroponic systems * Nutrient solution concentrations (dSm^{-1}) * number of irrigation times per day						
F-NFT	1.2 dSm^{-1}	24 per day	27.8 g	1043 cd	26.6 f	1109 d
		32 per day	28.5 g	1061cd	27.9 ef	1130 cd
		48 per day	29.0 fg	1080 bc	27.5 f	1140 cd
	1.5 dSm^{-1}	24 per day	29.5 efg	1071 bc	27.7 f	1120 cd
		32 per day	31.6 cde	1077 bc	31.5 cd	1135 cd
		48 per day	32.3 cd	1085 bc	31.7 cd	1152 bc
	1.8 dSm^{-1}	24 per day	32.2 cd	1100 bc	31.5 cd	1140 cd
		32 per day	36.9 a	1130 ab	36.9 a	1191 a
		48 per day	37.3 a	1150 a	36.9 a	1198 a
DWC	1.2 dSm^{-1}	24 per day	27.6 g	1015 d	25.9 f	1108 d
		32 per day	28.5 g	1053 cd	27.6 f	1119 d
		48 per day	28.8 fg	1061cd	27.8 ef	1124 cd
	1.5 dSm^{-1}	24 per day	29.4 fg	1057 cd	27.7 ef	1132 cd
		32 per day	29.3 fg	1060 cd	28.7 ef	1119 cd
		48 per day	31.0 def	1095 bc	31.0 cd	1129 cd
	1.8 dSm^{-1}	24 per day	31.6 cd	1068 cd	30.4 de	1128 cd
		32 per day	33.5 bc	1093 bc	33.7 bc	1133 cd
		48 per day	35.5 ab	1123 ab	35.3 ab	1175 ab

The interaction between hydroponic systems and number of irrigation times per day, noticed that irrigation 48 times daily in flat nutrient film technique (F-NFT) gave the highest N content in lettuce leaves than other treatments. As for the P and K contents, the highest values recorded in the flat nutrient film technique (F-NFT) followed by deep water culture (DWC) with 48 irrigation times per day without any significant difference between them. On the centenary, the lowest values of N, P and K contents recorded by 24 irrigation times per day with deep water culture (DWC).

The interaction between nutrient solution concentrations and irrigation number per day, date illustrated that the highest N, P and K contents were recorded in the interaction of nutrient solution concentration 1.8 dSm^{-1} with irrigation by 48/per day. On the other hand, a nutrient solution concentration of 1.2 dSm^{-1} with number of irrigation 24 per day gave the lowest values.

Regarding to the effect of second-order interaction among hydroponic systems, nutrient solution concentrations and number of irrigation times per day on contents of N, P and K in leaves presented in (Table, 9). The highest contents of N, P and K were obtained with combination of the flat nutrient film technique (F-NFT), nutrient solution concentration 1.8 dSm^{-1} and irrigation 48 times per day. On the contrary, the lowest N, P and K contents were found in the combination of deep water culture (DWC), nutrient solution concentration 1.2 dSm^{-1} and irrigation 24 times per day.

Table 8: Effect of first-order interaction between hydroponic systems, nutrient solution concentrations and number of irrigation times per day on contents of N, P and K (%) in lettuce leaves during 2022-2023 seasons.

Treatment combination		First season			Second season		
		N	P	K	N	P	K
Hydroponic systems * Nutrient solution concentrations (dSm^{-1})							
F-NFT	1.2 dSm^{-1}	2.47 d	0.84 c	1.13 c	2.23 e	0.83 c	1.16 d
	1.5 dSm^{-1}	2.60 c	0.85 bc	1.21 b	2.56 c	0.86 b	1.27 c
	1.8 dSm^{-1}	3.79 a	0.89 a	1.36 a	3.47 a	0.89 a	1.42 a
DWC	1.2 dSm^{-1}	2.29 e	0.82 d	1.09 d	2.22 e	0.79 d	1.10 e
	1.5 dSm^{-1}	2.56 cd	0.85 bc	1.20 b	2.35 d	0.81 cd	1.23 c
	1.8 dSm^{-1}	3.35 b	0.87 ab	1.33 a	3.15 b	0.86 b	1.37 b
Hydroponic systems * Number of irrigation times per day							
F-NFT	24 per day	2.77 c	0.81 c	1.17 c	2.57 d	0.82 c	1.20 d
	32 per day	2.97 ab	0.86 b	1.27 a	2.70 b	0.85 b	1.31 a
	48 per day	3.12 a	0.91 a	1.28 a	2.99 a	0.92 a	1.33 a
DWC	24 per day	2.56 d	0.77 d	1.16 c	2.48 e	0.74 d	1.19 d
	32 per day	2.79 c	0.86 b	1.22 b	2.58 cd	0.82 c	1.23 c
	48 per day	2.85 bc	0.90 a	1.24 ab	2.66 bc	0.90 a	1.28 b
Nutrient solution concentrations (dSm^{-1}) * number of irrigation times per day							
1.2 dSm^{-1}	24 per day	2.16 e	0.77 f	1.06 f	2.12 f	0.72 e	1.08f
	32 per day	2.54 d	0.83 d	1.14 e	2.27 e	0.80 d	1.12 e
	48 per day	2.43 d	0.89 b	1.12e	2.28 e	0.90 b	1.18 d
1.5 dSm^{-1}	24 per day	2.59 d	0.80 e	1.14 e	2.33 e	0.81 d	1.16 de
	32 per day	2.59 d	0.86 c	1.23 d	2.36 e	0.83 d	1.28 c
	48 per day	2.57 d	0.89 b	1.26 cd	2.67 d	0.88 bc	1.31 bc
1.8 dSm−1	24 per day	3.25 c	0.80 de	1.29 c	3.12 c	0.82 d	1.34 b
	32 per day	3.51 c	0.89 b	1.36 b	3.29 b	0.86 c	1.41 a
	48 per day	3.96 a	0.94 a	1.40 a	3.52 a	0.95 a	1.44 a

Table 9: Effect of second-order interaction among hydroponic systems, nutrient solution concentrations and number of irrigation times per day on contents N, P and K (%) in lettuce leaves during 2022-2023 seasons.

Treatment combination			First season			Second season		
			N	P	K	N	P	K
Hydroponic systems * Nutrient solution concentrations (dSm^{-1}) * number of irrigation per day								
F-NFT	1.2 dSm^{-1}	24 per day	2.21 gh	0.80 fg	1.06 h	2.12 f	0.76 f	1.08 i
		32 per day	2.55 fg	0.83 ef	1.18 f	2.25 ef	0.81 de	1.16 gh
		48 per day	2.64 f	0.90 bc	1.15 fg	2.30 e	0.91 ab	1.23 ef
	1.5 dSm^{-1}	24 per day	2.62 f	0.81 fg	1.14 fg	2.31 e	0.85 cd	1.20 fg
		32 per day	2.65 ef	0.85 de	1.25 de	2.40 e	0.86 c	1.32 cd
		48 per day	2.54 fg	0.89 cd	1.25 de	2.97 d	0.89 bc	1.28 de
	1.8 dSm^{-1}	24 per day	3.48 bc	0.83 ef	1.29 cd	3.27 bc	0.85 cd	1.32 cd
		32 per day	3.70 b	0.90 bc	1.37 ab	3.44 b	0.87 bc	1.45 ab
		48 per day	4.18 a	0.95 a	1.43 a	3.69 a	0.96 a	1.49 a
DWC	1.2 dSm^{-1}	24 per day	2.11 h	0.74 h	1.06 h	2.12 f	0.68 g	1.08 i
		32 per day	2.54 fg	0.83 ef	1.10 gh	2.28 ef	0.79 ef	1.09 hi
		48 per day	2.23 gh	0.87 cd	1.10 gh	2.25 ef	0.89 bc	1.14 ghi
	1.5 dSm^{-1}	24 per day	2.56 fg	0.80 fg	1.14 fg	2.35 e	0.77 ef	1.12 ghi
		32 per day	2.52 fg	0.86 cde	1.20 ef	2.33 e	0.80 ef	1.24 ef
		48 per day	2.61 f	0.89 cd	1.27 d	2.37 e	0.87 c	1.33 cd
	1.8 dSm^{-1}	24 per day	3.01 de	0.78 gh	1.29 cd	2.97 d	0.78 ef	1.37 c
		32 per day	3.31 cd	0.89 cd	1.34 bc	3.13 cd	0.86 c	1.37 c
		48 per day	3.73 b	0.93 ab	1.37 ab	3.36 b	0.94 a	1.38 bc

3.4 Water Use Efficiency (Kg/m^2) and Power Use Efficiency (Kilowatt/m^2).

The effect of hydroponic systems, nutrient solution concentrations and number of irrigation times per day on water use efficiency (Kg/m^2) and power use efficiency (Kilowatt/ m^2) of lettuce plants shown in (Figures 3 and 4). Using flat nutrient film technique system (F-NFT) gave the highest water and power use efficiency with significant difference with deep water culture system (DWC). Increasing the concentration of nutrient solution up to 1.8 dSm^{-1} was accompanied by successive and significant increases in the water and power use efficiency. Increasing the number of irrigation times per day to 48 per day lead to an increase in the water use efficiency, while, decreasing the power use efficiency.

The effect of first-order interactions on water and power use efficiency presented in (Table, 10). Concerning the effect of the interaction between hydroponic systems and nutrient solution concentrations indicated that the highest values of water and power use efficiency obtained with flat nutrient film technique (F-NFT) + nutrient solution concentration 1.8 dSm^{-1}. While, the lowest value was achieved with deep water culture system (DWC) with a nutrient solution concentration 1.2 dSm^{-1}.

Moreover, applied number of irrigation times 48/day in flat nutrient film technique gave the highest WUE value, while, the lowest value of WUE was recorded with deep water culture + number of irrigation times 24 per day. On the other hand, using flat nutrient film technique with number of irrigation times 24/day gave the highest power use efficiency (PUE), while, the lowest value was estimated by using deep water culture with irrigation times 48 per day.

The interaction between nutrient solution concentrations and number of irrigation times per day indicated that the irrigated lettuce plants by 48 times per day plus nutrient solution concentration 1.8 dSm^{-1} followed by 1.5 dSm^{-1} gave the highest water use efficiency without any significant difference. The lowest values were recorded in the combination of nutrient solution concentration 1.2 dSm^{-1} with 24 times of irrigation per day. Although, the highest value of power use efficiency was found with nutrient solution concentration 1.8 dSm^{-1} + number of irrigation 24 times per day and the lowest power use efficiency was estimated by using nutrient solution concentration 1.2 dSm^{-1} with 48 times of irrigation per day.

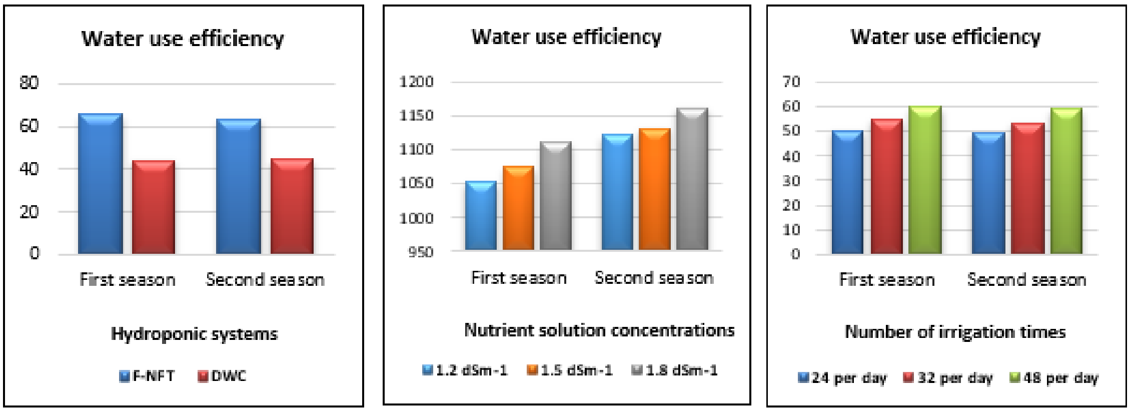

Figure 3: Effect of hydroponic systems, nutrient solution concentrations and number of irrigation per day on water use efficiency (Kg/m²) as an average of 2022-2023 seasons.

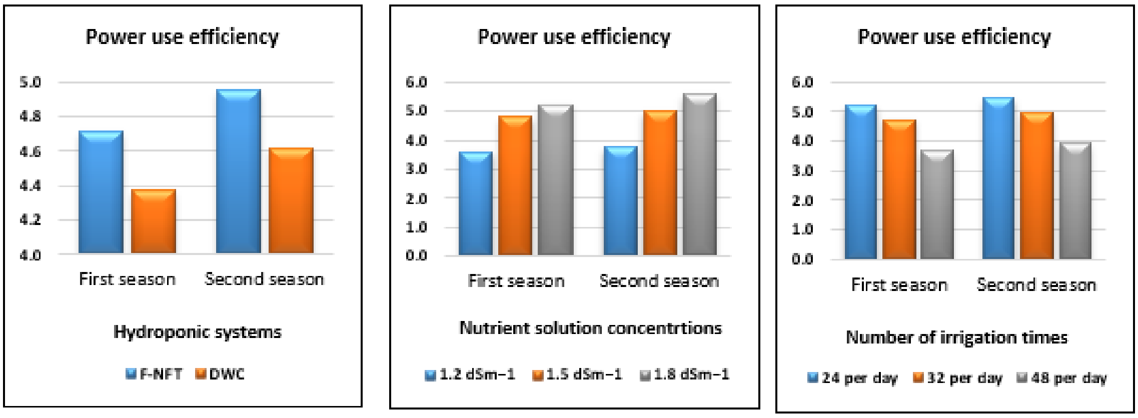

Figure 4: Effect of hydroponic systems, nutrient solution concentrations and number irrigation times per day on power use efficiency (Kilowatt/m²) as an average of 2022-2023 seasons.

Table 10: Effect of first-order interaction between hydroponic systems, nutrient solution concentrations and number of irrigation times per day on water use efficiency (Kg/m²) and power use efficiency (Kilowatt/m²) as an average of 2022-2023 seasons.

Treatment combination		First season		Second season	
		Water use efficiency	Power use efficiency	Water use efficiency	Power use efficiency
Hydroponic systems * Nutrient solution concentrations (dSm^{-1})					
F-NFT	1.2 dSm^{-1}	57.9 c	3.66 d	56.6 c	3.81 e
	1.5 dSm^{-1}	67.8 b	4.90 b	65.2 b	5.13 c
	1.8 dSm^{-1}	70.6 a	5.57 a	68.4 a	5.91 a
DWC	1.2 $dS\ m^{-1}$	41.5 e	3.54 d	42.9 e	3.71 e
	1.5 $dS\ m^{-1}$	45.4 d	4.69 c	45.4 d	4.87 d
	1.8 $dS\ m^{-1}$	45.9 d	4.88 b	44.7 d	5.27 b
Hydroponic systems * Number of irrigation times per day					
F-NFT	24 per day	62.8 c	5.41 a	61.4 b	5.64 a
	32 per day	65.3 b	4.96 b	62.8 b	5.18 c
	48 per day	68.3 a	3.77 d	65.9 a	4.02 e
DWC	24 per day	37.5 f	5.00 b	36.9 e	5.29 b
	32 per day	44.1 e	4.51 c	43.6 d	4.72 d
	48 per day	51.2 d	3.60 e	52.5 c	3.84 f
Nutrient solution concentrations (dSm^{-1}) * Number of irrigation times per day					
1.2 dSm^{-1}	24 per day	45.7 g	4.24 e	44.4 e	4.42 e
	32 per day	48.6 f	3.66 f	48.8 d	3.78 f
	48 per day	54.8 d	2.90 g	56.0 b	3.07 g
1.5 dSm^{-1}	24 per day	51.4 e	5.46 c	49.8 d	5.70 c
	32 per day	56.8 c	4.87 d	54.8 bc	4.99 d
	48 per day	61.7 a	4.06 e	60.4 a	4.32 e
1.8 dSm^{-1}	24 per day	53.4 d	5.92 a	53.2 c	6.27 a
	32 per day	58.7 b	5.67 b	56.0 b	6.10 b
	48 per day	62.7 a	4.09 e	61.2 a	4.40 e

Table 11: Effect of second-order interaction among hydroponic systems, nutrient solution concentrations and number of irrigation times per day on water use efficiency (Kg/m²) and power use efficiency (Kilowatt/m²) as an average of 2022-2023 seasons.

Treatment combination			First season		Second season	
			Water use efficiency	Power use efficiency	Water use efficiency	Power use efficiency
Hydroponic systems * Nutrient solution concentrations (dSm^{-1}) * Number of irrigation times per day						
F-NFT	1.2 dSm^{-1}	24 per day	55.6 f	4.38 e	54.5 d	4.57 ef
		32 per day	56.0 f	3.69 gh	55.1 d	3.81 i
		48 per day	62.0 e	2.92 i	60.1 c	3.05 i
	1.5 dSm^{-1}	24 per day	63.8 d	5.48 b	61.3 bc	5.70 bc
		32 per day	69.3 c	5.05 c	65.6 ab	5.20 b
		48 per day	70.4 b	4.17 ef	68.6 a	4.48 fg
	1.8 dSm^{-1}	24 per day	68.9 c	6.36 a	68.4 a	6.65 a
		32 per day	70.5 b	6.13 a	67.8 a	6.54 a
		48 per day	72.3 a	4.21 ef	68.9 a	4.53 f
DWC	1.2 dSm^{-1}	24 per day	35.8 m	4.09 ef	33.3 g	4.28 gh
		32 per day	41.2 j	3.63 h	42.6 e	3.75 i
		48 per day	47.5 h	2.88 i	52.0 d	3.09 j
	1.5 dSm^{-1}	24 per day	39.0 k	5.44 b	38.3 f	5.70 bc
		32 per day	44.3 i	4.69 d	44.1 e	4.77 e
		48 per day	52.9 g	3.95 fgh	53.7 d	4.15 h
	1.8 dSm^{-1}	24 per day	37.8 l	5.48 b	38.0 f	5.88 b
		32 per day	46.8 h	5.21 bc	44.2 e	5.66 c
		48 per day	53.1 g	3.97 fg	51.8 d	4.27 h

Table 12: Total construction costs (L. E.) of two hydroponic systems as an average of 2022-2023 seasons.

Systems combination	Pipes	Holder	Tank	Timer	Irrigation system	Pump	Net cups	Establishment cost	construction basin	Foam sheets	Black sheet (1mm)	T. investment costs (L. E.)
Flat NFT	90	75	11	45	10	45	15	25	0	0	0	316
DWC	0	0	0	45	5	45	15	25	37.5	30	45	247.5

Table 13: Total operation costs (L. E.) of hydroponic systems, nutrient solution concentrations and number of irrigation times per day as an average of 2022-2023 seasons.

Treatments			**Seedlings**	**Chemicals**	**Substrate**	**electricity**	**Irrigation**	**Others**	**Total operation costs**
systems	**EC**	**Irrigation time**							
NFT	**1.2**	**24**	450	46	180	227	14	600	1516
		36	450	50	180	303	15	600	1598
		48	450	55	180	454	16	600	1755
	1.5	**24**	450	62	180	227	15	600	1534
		36	450	71	180	303	17	600	1621
		48	450	75	180	454	18	600	1777
	1.8	**24**	450	80	180	227	16	600	1553
		36	450	103	180	303	23	600	1658
		48	450	162	180	454	32	600	1878
DWC	**1.2**	**24**	450	67	180	227	20	600	1544
		36	450	66	180	303	20	600	1618
		48	450	67	180	454	20	600	1772
	1.5	**24**	450	101	180	227	24	600	1582
		36	450	99	180	303	24	600	1656
		48	450	106	180	454	26	600	1815
	1.8	**24**	450	126	180	227	25	600	1608
		36	450	134	180	303	27	600	1694
		48	450	132	180	454	26	600	1842

Table 14: Net profit (L. E.) of hydroponic systems, nutrient solution concentrations and number of irrigation times per day as an average of 2022-2023 seasons.

Treatment combination			Investment costs (L. E.)	Production costs (L. E.)	Total costs (E. L.)	Total yield (Kg)	Price per (L. E./Kg)	Total return (L. E.)	Net Profit (L. E.)
Hydroponic systems	**EC**	**Irrigation time**							
NFT	**1.2**	**24**	316	1516	1832	150	30	4511	2678
		36	316	1598	1914	168	30	5040	3126
		48	316	1755	2071	201	30	6019	3948
	1.5	**24**	316	1534	1850	188	30	5634	3784
		36	316	1621	1937	230	30	6890	4954
		48	316	1777	2093	291	30	8719	6626
	1.8	**24**	316	1553	1869	219	30	6556	4687
		36	316	1658	1974	284	30	8514	6540
		48	316	1878	2194	294	30	8813	6618
DWC	**1.2**	**24**	248	1544	1792	141	30	4219	2427
		36	248	1618	1866	165	30	4961	3095
		48	248	1772	2019	201	30	6023	4004
	1.5	**24**	248	1582	1829	187	30	5616	3787
		36	248	1656	1904	212	30	6354	4450
		48	248	1815	2063	272	30	8161	6098
	1.8	**24**	248	1608	1856	191	30	5728	3872
		36	248	1694	1941	243	30	7301	5360
		48	248	1842	2090	277	30	8305	6215

3.5 Economic Study

Tables (12, 13 and 14) shown the economic study of cultivation Batavia green lettuce production under hydroponic systems during the winter seasons of 2022 and 2023. Data illustrated that the interaction among flat nutrient film technique (F-NFT), nutrient solution concentration 1.8 dSm^{-1} and number of irrigation 48 times per day recorded the highest total cost (2194 E. L.). While, the lowest costs were recorded with the combined deep water culture (DWC), 1.2 dSm^{-1} and 24 irrigation times per day (1792 E. L.). On the other hand, the highest total return was recorded with the combining of flat nutrient film technique (F-NFT), 1.8 dSm^{-1} and 48 irrigation times per day (8813 E. L.) and the highest net profit was recorded with the interaction among flat nutrient film technique (F-NFT), 1.5 dSm^{-1} and number of irrigation 48 times per day (6626 E. L.). While, the lowest total return and net profit were recorded by the combined among deep water culture, 1.2 dSm^{-1} and 24 irrigation times per day (4219 and 2427 E. L., respectively).

4. Discussion

From the overall results, data showed that using the flat nutrient film technique (F-NFT) increased all measurements under study as the number of leaves, plant fresh weight, total yield (Kg/m^2), chlorophyll reading (SPD), nitrate content (ppm), N, P and K contents (%), water use efficiency/m^2 and power use efficiency per m^2, compared with deep water culture system (DWC). This due to the dynamics of water flow and the nature of root growth in the (F-NFT) are better than in deep-water culture, which contributed to improving the supply of water, oxygen and nutrients to plants, and led to the increase in yield. The obtained results are in agreement with whom, reported that in the nutrient film technique (NFT) the root grows partially immersed in the nutrient solution that improves the aeration around the root area which allowed the roots to grow and develop in an environment that was favorable for their absorption of dissolved oxygen and nutrient resulting in an increase in vegetative growth and yield parameters (Jong et al., 2014; Roosta et al., 2016; Helmy et al., 2021; Velazquez-Gonzalez et al., 2022). On the contrary, in deep water culture, the root grown completely immersed in a nutrient solution which decreased the aeration around the root area that led to reduce root growth, ion uptake, and water uptake, resulting in lower plant growth and consequently lower yield. According to water flow dynamics in nutrient film technology (NFT) relies on pumping a nutrient solution to the ends of the tubes and then returning it to the tank by gravity, whereas, in depth water culture water flow dynamics depends on circulating water in the system (Abul-Soud et al., 2019, 2020). As a result, the dissolved oxygen in the NFT solution is more than in the deep water culture system, which contributes to the increase in yield. It has investigated several hydroponic systems and demonstrated that NFT hydroponic system was 6% –10% more effective than the deep water culture system (DWC) system in enhancing the yield of lettuce (Frasetya et al., 2020). Moreover, studied the effect of three different hydroponics systems, nutrient film technique (NFT), deep water culture (DWC), and substrate culture (SC) on lettuce production (Kyle, 2021). The results showed that the use of the nutrient film technique (NFT) gave the highest head fresh weight, dry weight of lettuce plant, chlorophyll reading and nitrate content at save recommended ranges compared with deep water culture.

Regarding to the effect of the nutrient solution concentrations, the data showed that increasing the nutrient solution concentration from 1.2 to 1.8 dSm^{-1} increased all of the study's parameters. The satisfactory effect of increasing the concentration of the nutrient solution to 1.8 dSm^{-1} due to achieving the optimal nutrient requirements of lettuce plants, which had a direct impact on the growth and development of lettuce plants, while, the low concentrations of the nutrient solution (1.2 EC) adversely affect plant growth due to nutrient deficiencies in the nutrient solution as concluded by (Serio et al., 2000). reported that under lower nutrient solution concentrations the supply of some nutrients to the crop may be inadequate and accompanied by decreasing yield (Samarakoon et al., 2006). According, studied the effect of nutrient solution concentration (0.92, 1.39 and 1.80 dSm^{-1}) on fresh mass accumulation in the above ground part and roots of different lettuce cultivars (Genuncio et al., 2012). They found that increasing the nutrient solution concentration to 1.8 dSm^{-1} increased the fresh mass of the above ground part for Lucy Brown, Isabella and Veronica cultivars at hydroponic systems. This enhancement due to the ionic concentration of the nutrient solution is a key factor in the regulation of stomata opening (through the osmotic potential), photosynthetic efficiency, and leaf growth. Low nutrient concentrations have a negative effect on root respiration, nutrient uptake, and ultimately plant growth. investigated lettuce cultivars (butter green and butter red) cultivated at four EC levels: 0.8, 1.2, 1.8, and 2.4 dSm^{-1} (Samarakoon et al., 2019). The highest fresh and dry weights, photosynthetic rate, and N, P and K levels content were recorded with EC 1.8 dSm^{-1} without a difference with 2.4 dSm^{-1}. While N and K uptake by leaves were increased with increasing EC to 2 dSm^{-1}. To determine the effects of nutrient solution concentration on the lettuce studied different concentrations of the nutrient solution (0.3, 1.2, 2, 2.8, and 3.6) and they found that nitrate contents increase as nutrient solution concentration rise (Fallovo et al., 2009).

Considering the influence of number of irrigation per day, data reflected that increasing the number of irrigation per day improved all vegetative growth parameters, yield, leaves contents from N, P and K, chlorophyll reading, nitrates content, water use efficiency/m^2 and decreased the power use efficiency/m^2. These results can be explained by the fact that increasing the number of irrigation times per day directly contributed to the maintenance of moisture levels, better nutrient uptake conditions, and the stability of oxygen level and temperature in the root zone and these results were in agreement with how mentioned that, irrigation frequency a day led to increased fresh weight and yield (Silber et al., 2003; Xu et al., 2004).

Regarding to economic study, obtained that the combined flat nutrient film technique (NFT) + irrigation by 48 times/day + nutrient solution concentration 1.8 dSm^{-1} gave the highest total return. While, NFT + irrigation by 48 times/day + nutrient solution concentration 1.5 dSm^{-1} recorded the highest net profit. This is due to the increasing the cost of nutrient solution concentration 1.8 dSm^{-1} more than nutrient solution concentration 1.5 dSm^{-1} and have not produce yield covering the increasing in price of nutrient solution. The same explanation is observed in on tomato crops (Tatiana et al., 2017).

5. Conclusion

The obtained results indicated that using the flat nutrient film technique (NFT), with 48 irrigation time per day and nutrient solution concentration from 1.5 $dS{\cdot}m^{-1}$ achieved the best agronomic productivity and economic profit for lettuce crop production.

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