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Effect of Different Substrates and Nutrient Solutions on Growth and Productivity of Soilless Cultured Head Lettuce with using Solar Energy for Operating Fertigation System

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ABSTRACT

This investigation was carried out at Soilless Culture Unit, Agric. Faculty., Mansoura Univ., Egypt, during both consecutive winter seasons of 2020/2021 and 2021/2022, to investigate the influence of three substrate mixes; peat moss : perlite, 1:1 (PP), peat moss : vermiculite, 1:1 (PV) and peat moss : perlite : vermiculite, 1:1:1 (PPV), divers three nutrient solutions; Cooper (CO), Hoagland (HO) and Hewitt (HE) and their combinations on soilless cultured head lettuce (cv. Big Bell) productivity and quality. The obtained results clearly demonstrated that all tested attributes of lettuce as vegetative growth (plant height, foliage and leaf fresh weight/plant and leaf number and area/plant), both photosynthetic pigment concentration (chlorophyll$_{a,b}$ and carotenoids) and (N, P and K %) of fresh and dry outer leaves, respectively, heads yield (head fresh weight, edible head fresh weight, heads yield per A-shaped unit and per fed.), edible head quality (vitamin C, TSS, acidity, diameter and compactness), and protein, carbohydrate and nitrate (NO_3) content of edible head leaves dry matter were significantly influenced by all studied factors and their interactions. The best significant values for all mentioned parameters were achieved with PPV mixture and CO nutrient solution as compared with PV and HE ones. Therefore, it could be recommended that substrate cultures of head lettuce plants in A-shaped PVC pipe units containing PPV mixture and feed with CO nutrient solution through fertigation system operated by renewable, cheap and environmentally friendly solar energy are the optimum choice for achieving satisfactory growth and plant performance.

***Keywords*:** Head lettuce (cv. Big Bell) growth and productivity, soilless culture, substrates (growing media), nutrient solutions, solar energy (PV panel).

INTRODUCTION

Head lettuce (*Lactuca sativa* var. *capitata* L.), which belongs to the daisy family Asteraceae (Compositae) is a cool-season crop and an annual self-pollinated plant. It is one of the most popular and important leafy vegetables for fresh consumption by many consumers around the world. Different lettuce types contain various dietary contents significant for human health such as fibers, minerals (Fe, Mn, Zn, Ca, K, P and Mg), vitamins (A, B1, B6, C, E and K), and other health-promoting bioactive compounds such as carotenoids (i.e., β-carotene and lutein), phenolic acids (Stojanovic *et al*., 2023) and α-linolenic acid (an omega-3 polyunsaturated fatty acid) (Murray *et al*., 2021). In Egypt, the total cultured area of lettuce and chicory in 2021 was approximately 8790.5 feddan, which produced about 78850.83 ton with the average of 8.97 ton/feddan (FAO, 2023).

Traditional culture system (TCS) suffers from many problems that reduce its production capacity and thus increase the global food gap with decreasing its economic feasibility, especially in light of the massive and continuous population increase. Among the problems that reduce the productivity of TCS are: increased rates of secondary salinization and desertification of lands, scarcity of irrigation water and arable land, increased spread of plant diseases resulting from the abundance of pathogens and weed seeds borne in soil that required the excessive use of chemical fertilizers and pesticides and thus increasing environmental pollution and production of unclean products, inappropriate soil pH which makes many essential nutrients unavailable for plant roots and poor soil drainage, ventilation and fertility. All the previous problems and along with climate change make the lands weak and uncultivable (Dutta *et al*, 2023).

Soilless culture system (SCS) means cultivation of plants in nutrient solutions had suitable pH and EC either without or using non-soil solid growing media, which provide mechanical support to cultivated plants (Hamaiel *et al*., 2020 and Dutta *et al*, 2023). SCS can provide with several advantages and sustainable and economic solutions to all aforementioned problems facing TCS (Thakulla *et al*., 2021 and Praveen *et al*., 2022). It also contributes fundamentally to both systems of horizontal and vertical agricultural expansions by cultivating the roofs of buildings and areas that are impossible to cultivate using TCS and via plant intensification of high-productivity and quality plants per unit area, respectively. In addition to, SCS is beneficial in rationalizing the use of basic production requirements, especially irrigation water, fertilizers, pesticides and labour by increasing the efficiency of the units used for each of them, which leads to decreasing the total production costs. It also participates to providing fresh and healthy agricultural products, especially to residents of remote places far from urban areas and markets. Moreover, it is helpful in adapting to climate change and reducing the severity of the damage resulting from it through its contribution to increasing green vegetation cover.

Growing media or rooting media or substrates are synonyms used to express the materials, other than ordinary

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soils, that are placed in plant growing containers. Many organic growing substrates such as peat moss, fine bark, sawdust, coconut fibers and coir dust, etc., and inorganic ones such as vermiculite, perlite, pumice, expanded clay and plastic particles, rockwool and glasswool, etc. are used in SCS either alone or in mixes. Regardless, good growing substrate mixtures should have good nutrient supply, drainage, aeration, moisture retention and well-supported plants.

Providing plants with water and essential nutrients in the form of a balanced nutrient solution with pH and EC within the appropriate limits throughout the different plant growth stages, especially in SCS, is considered one of the basic factors limiting their success. The method of feeding plants with the nutrient solution varies according to the SCS used in terms of whether it is closed especially in hydroponic systems or open in substrate ones **(**Dutta *et al*, 2023). Currently, there are many universal nutrient solutions that can be used successfully in SCS such as Cooper, Hoagland, Hewitt, Steiner, Albert, etc. solutions.

Renewable energy sources (such as wind, hydraulic, geothermal, tidal, biomass and solar) are considered an urgent technological option for generating sustainable, clean, cheap and safe energy, especially in light of global climate changes resulting from the excessive use of non-renewable energy sources such as fossil fuels. One of the most promising renewable energy sources in these connections is solar energy, which converted to electricity by photovoltaic (PV) panels (Salem, 2016 and Ogbomo *et al*., 2017). Due to Egypt's proximity to the equator, it enjoys a large number of sunshine hours daily, especially during the summer season. The threat of desertification, scarcity of water for drinking and irrigation purposes, and the decline of expensive and polluting non-renewable energy sources are the current and future challenges to human life around the world. Consequently, the significant of PV systems is highlighted as efficient alternative to systems that depend on conventional energy, and the importance of water pumping systems that operated by PV system is also highlighted as an appropriate solution to water rarity, especially in remote and desert areas (Shepovalova *et al*., 2020, Matheswaran *et al*., 2021 and IBraheam and Aslan, 2023).

Therefore, the goals of this present study were to investigate the effect of different substrate mixtures, various nutrient solutions and their interactions on growth and productivity of head lettuce cv. Big Bell grown in soilless substrate culture of A-shaped PVC plastic pipe units, using renewable, sustainable, cheap and safe solar energy as alternative to diesel one to manage the fertigation system, especially on the building roofs and in remote areas.

MATERIALS AND METHODS

The present investigation was conducted in Soilless Culture Unit, Research Vegetable Farm, Vegetables and Ornamentals Dept., Faculty of Agric., Mansoura Univ., Egypt during two successive winter seasons of 2020/2021 and 2021/2022 to study the effect of different three mixtures of locally prepared growing substrates *i.e.*, peat moss:perlite (1:1, v/v), peat moss:vermiculite (1:1, v/v) and peat moss:perlite:vermiculite (1:1:1, v/v/v), and three nutrient solutions (Cooper, Hewitt and Hoagland) and their combinations on the growth, yield and quality of head (cabbage) lettuce (*Lactuca sativa* var. *capitata* L. cv. Big Bell) cultivated soilless in pyramid-shaped units, using renewable, cheap, health-safe and environmentally friendly solar energy to operate the feeding system.

Preparing and cultivating growing units.

Good prepared growing media mixtures were applied in equal amounts in A-shaped soilless culture unit PVC pipes according to the experimental treatments. Then uniform lettuce transplants (35 days old) were cultured on 1est of November in both growing seasons inside two-thirds of 4-inch diameter plastic PVC pipes filled with a wet mixture of one of the growing media mixtures in accordance with the previously mentioned treatments. The head lettuce transplants were planted inside the planting pipes in one row in hills 25 cm apart from each other, at a rate of 12 transplants per each pipe and 108 transplants per A-shape soilless culture unit (Figure 1- B). Each A-shape unit contains 9 white plastic PVC pipes with a diameter of 4 inches, a length of 3 meters and 4.7 mm thick, the upper third of which is cut longitudinally (Figure 1- A). All nine PVC pipes for each pyramid-shaped unit of the three units used in this study were assigned to one of the growing substrate mixtures described above. The actual area of each soilless culture unit was 6 m2 (4 m length and 1.5 m width).

(A) **(B)**

Figure 1. (A-B). A general view of pyramid-shaped soilless culture units used; (A) PVC plastic pipes for pyramid-shaped soilless culture units before planting them, (B) PVC plastic pipes for A-shaped soilless culture units after planting.

Every 3 cultured plastic PVC pipes in different places in each A-shaped unit were fed with one of the three aforementioned nutrient solutions used in this study. Head lettuce transplants which grown in the tubes of the soilless culture units were fed with the different nutrient solutions included in this study through a half-horsepower water pump, Calpeda model, attached to the components of the fertigation system, which is operated with electricity generated by a photovoltaic (PV) system. The total number of treatments in this research study was 9, and each treatment was represented by 3 plastic PVC pipes containing 36 head lettuce plants.

Components of the fertigation system.

The fertigation (feeding) system used in this study consists of a 210 L blue PC4R plastic tank connected to a 1/2 horsepower water pump (Figure 2- A) that draws the target nutrient solution from the plastic tank and pumps it through a drip irrigation network with black, no-drip polyethylene hoses of 16 mm diameter to the beginning of the pipes of the soilless culture units, then to black, drip polyethylene hoses of 16 mm diameter (4 L h^{-1} discharge) that are 25 cm apart from each other. The ends of black, no-drip polyethylene hoses with a diameter of 16 mm are connected to the fronts of black, drip polyethylene hoses with a diameter of 16 mm, which are located in the PVC pipes of each soilless cultivation unit by means of plastic valves of 16 mm diameter in order to control the feeding of plants grown in the pipes of each unit with different nutrient solutions (Figure 2- B).

(A) (B)

Figure 2. (A-B): A general view of the fertigation system used; (A) the water pump is attached to the plastic feed tank, (B) distribution of drip irrigation hoses branching off from the water pump into the pipes of soilless culture units.

Management of nutrient solutions.

Each nutrient solution used in this study was represented by two plastic bottles (A&B), each with a capacity of 20 L, concentrated 100 times one of the chemical salts of the target nutrient solution. Plastic jar A was designated for the calcium nitrate salt solution only, while plastic jar B was allocated to the rest of the macro- and micronutrient salts of the target nutrient solution. When feeding plants, a nutritional solution is prepared diluted with an amount of fresh Nile water, resulting from mixing a specific amount of both concentrated solution A and B of the target nutrient solution in the feeding tank, to the required volume needed to feed the plants, taking into account adjusting the pH and EC values of the final diluted nutrient solution within optimum limits.

The pH of the nutrient solution that the plants are fed with should always be adjusted to 6-6.5 and the concentration of salts should be set to be about 600 parts per million (ppm) in the first third of the plant's life, then about 750 ppm in the middle third and then about 900 ppm in the last third. During the first third of the plants' life (the first 21 days), each plant is fed 7 times with approximately 250 cm^3 of a diluted nutrient solution of 600 ppm. Whereas during the middle third of the plants' lives (the second period of 21 days), each plant is fed 7 times with approximately 350 cm^3 of a diluted nutrient solution with a concentration of 750 ppm. While during the last third of the plants' lives (the third 21-day period), each plant is also fed 7 times with approximately 450 cm^3 of a diluted nutrient solution with a concentration of 900 ppm. At the end of each feeding time, only about 50 cm^3 of fresh water is pumped into each plant to wash the drip irrigation network and ensure that the drippers are not clogged. Approximately five days before harvest, the nutrient solution was replaced to fresh water to decrease nitrate accumulation in the head lettuce leaves. The concentrations of macro- and micro-nutrients of the three nutrient solutions used in this investigation were shown in Table (1).

Table 1. The concentration of macro- and micro-nutrients in the Hoagland, Hewitt and Cooper nutrient solutions.

Nutrient	Hoagland	Hewitt	Cooper
	Concentration at ppm		
N	210	168	218
P	31	41	60
K	234	156	300
Ca	160	160	178
Mg	34	36	50
S	64	48	68
Fe	2.5	2.8	12
Mn	0.5	0.54	2.0
B	0.5	0.54	0.3
Zn	0.05	0.065	0.1
Cu	0.02	0.064	0.1
Mo	0.01	0.04	0.2

4. Components of the solar PV System.

The solar PV system is composed of a number of major components such as; solar panels, inverter and other electrical components e.g. solar batteries, wires and solar charge controller (Figure 3- A). It is able to convert solar radiation into electrical energy. The generated electrical energy by the solar PV system can be delivered directly to power the target load, or it can be stored in solar batteries for later use.

PV panels:

The PV panels can be arranged in arrays to increase electrical energy production. The arrays are installed on a metal frame, the angle of inclination of which can be changed manually. Two solar panels connected in parallel were used to generate energy which needed to operate the water pumping system. The model of PV panels used in this investigation was SolarWorld {Sunmodule plus SW 250 poly (250 watt)}. The photovoltaic panels used and their characteristics are shown in the following figure (3- B).

(A) (B)

Figure 3. (A-B): A general view of the PV panel system used; (A) the main components of a PV panel system (PV panel, inverter, solar batteries, DC and AC wiring, safety switches, and circuit breakers that are installed between the inverter, batteries, and load), (B) characteristics of the PV panels used.

Inverter:

Inverter (Figure 3-A), model must (1 KW, 12 V) has power equal 570 watt and transforms the DC power generated by the PV system to AC power needed to operate the water pump motor. Also, it protects the solar PV system from the damage owing to shortness. In addition to, it adjusts the output frequency in real time in accordance with the predominant irradiation rates. Moreover, it is useful in purifying and stabilizing the voltage among the battery, PV system and the load. Additionally, it works with MPPT (Maximum Power Point Tracking) technology to maximize power production at all irradiation rates. The other important electrical components required to control and prevent the system from damage (Figure 3-A) are, DC wires (4 mm^2, and 6 m length), and safety switches like, two fuses (20 amp. for each) and circuit breaker (CB, 32 amp.) which is installed before the inverter and another one (CB, 10 amp) is installed after the inverter to connect and disconnect the load and to protect the inverter.

Solar battery:

Solar battery is one of the most important components for storage of electrical energy. Two batteries, model ACDelco (90 A, 12 V for each one) as shown in Figure (3-A) were connected in PV system series to storage the electrical energy to balance the system and for use at night or when it is needed.

Pump components:

A centrifugal water pump, Calpeda model, with AC motor 0.5 HP (439 W, 2.3 m^3/h, 1500 rpm), valves, connections (1 inch, let and outlet diameter), as shown in Figure (2-A).

Experimental design:

The experiment was designed in split-plot design with 3 replications. Where, the main plots were allotted to three growing media mixtures, while the sub-plots were allocated to three nutrient solutions.

The measurements:

After 65 days of planting date, 15 head lettuce plants were randomly cropped from each treatment to determine the following characters:

Vegetative growth traits:

Plant height, foliage fresh weight/plant (outer and inner stem plus outer and inner leaves), leaves fresh weight/plant, leaves number/plant and leaves area/plant were estimated.

Outer leaves chemical composition:

Chlorophyll a (Chl.a), chlorophyll b (Chl.b) and carotenoid contents of the fresh outer leaves and the percentages of N, P and K of the dry matter of head lettuce outer leaves were analyzed in accordance to AOAC (1990).

Heads yield components and its physical quality:

Head fresh weight/plant (outer and inner leaves + inner stem), edible head fresh weight/plant (inner stem + firm and compacted inner leaves), edible head diameter, heads yield/poly vinyl chloride pipes unit (head yield/PVC P unit) and heads yield/fed were recorded. Edible head compactness rate was calculated according to (Riad *et al.*, 2009) as given in the following equation:

$$\text{Compactness rate} = \frac{\text{Edible head volume } (0.75 \times 3.14 \times \text{radius}^3)}{\text{Edible head fresh weight}}$$

Edible heads chemical quality:

Vitamin C (VC), total soluble solids (TSS) and total acidity (TA) of the fresh edible head and protein, carbohydrate and nitrate (NO_3) content of the dry matter of edible head lettuce were estimated according to AOAC (1990).

The total cost of PV system.

The total cost (LE/h) was computed according to (Awady, 1978) as presented in the following equation:

$$C = \frac{p}{h}\left(\frac{1}{e} + \frac{i}{2} + t + r\right) + w + \frac{m}{mh}$$

Where: p= price of system (LE), h= yearly working hours, e= life expectancy (year), i = interest rate (%), t= taxes (%), r= maintenance, w= fuel cost (LE/h), m= monthly wages (LE/month) and mh= monthly average working hours (180 h).

Cost of producing energy.

The cost of producing energy (LE/KW.h) was calculated according to the following equation:

$$CP = \frac{p}{e \times 365}$$

Where: CP= cost of producing energy (LE/KW.h), p= price of system (LE), e= life expectancy (year), and 365= year days number.

Operating cost of water pump.

The operating cost (LE/m^3 irrigation water) was estimated according to the following equation:

$$CO = \left(\frac{wpc}{1000}\right) \times cp$$

Where: CO= operating cost of water pump, wpc= water pump capacity, and cp= cost of producing energy.

Statistical Analysis:

Data were statistically analyzed employing the analysis of variance (ANOVA) method as described by Gomez and Gomez (1984). The treatment averages were compared using the least significance difference (LSD) test at 5 % probability level as reported by Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

Vegetative growth characters:

The effect of substrate mixtures (PP, PV and PPV), nutrient solutions (CO, HO and HE) and their combinations on head lettuce vegetative growth parameters (plant height, foliage and leaves fresh weight per plant, leaves number and area per plant in the first and second seasons are presented in Table (2). Regarding the impact of growing media mixtures, data given in Table (2) reveal that all forecited characters had been influenced significantly by all diver growing media mixtures in both consecutive seasons, successively. The highest values in this regard were accomplished with PPV mixture, while the lowest values were achieved with the PV one.

Concerning the effect of nutrient solutions, data presented in Table (2) obviously indicate that all the previous parameters significantly had been affected by all nutrient solutions in the first and second seasons, without significant differences between both CO and HO nutrient solutions. The maximum values were registered with the CO, whereas the minimum values were recorded with HE one

As for the influence of combination treatments, results listed in the same table also mainly illustrate that the mentioned attributes were significantly had been impacted by all various interaction treatments in both seasons. The best means in this regard were achieved with the interaction treatment of PPV mixture + CO nutrient solution. Whilst, the lowest means were attained with the interaction treatment of PV mixture + HE nutrient solution. The rest interaction treatments recorded values between these two extremes. These results are in the same line with those of Hamaiel *et al.* (2020); El-Biyaly (2021), Soylemez, 2021, Uy *et al.* (2021), Nasih *et al.* (2022) on lettuce and Gaikwad *et al.* (2020) on spinach.

Table 2. Effect of different substrate mixtures, nutrient solutions and their interactions on vegetative growth parameters of soilless cultured head lettuce during 1st and 2nd seasons after 65 days from transplanting.

Characters		Plant height (cm)		Foliage FW* (g/ plant)		Leaves No. /plant		Leaves FW* (g /plant)		Leaves area(cm^2/plant)	
Treatments		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st Season	2nd season
Substrate mixtures											
PP		20.3	20.7	429.53	461.58	44.8	46.1	378.25	420.56	3611.6	3830.4
PV		19.4	19.7	371.01	394.54	42.8	42.7	371.04	365.92	3138.3	3209.9
PPV		20.7	21.2	456.97	480.58	45.7	46.7	415.57	440.46	3857.6	4136.7
LSD 5%		0.7	0.6	42.39	60.70	2.1	3.2	40.30	54.94	292.4	645.1
Nutrient solutions											
CO		21.1	21.6	473.97	515.91	46.5	47.9	434.22	458.46	4096.1	4181.3
HO		20.6	20.9	433.64	451.31	45.3	45.7	402.85	419.96	3624.0	3813.4
HE		18.7	19.1	349.90	369.48	41.5	41.9	327.80	348.52	2887.4	3182.3
LSD 5%		0.9	1.3	38.74	54.02	2.9	3.9	33.61	49.92	397.8	516.2
Interaction between substrate mixtures and nutrient solutions											
	CO	21.3	21.9	496.75	543.53	46.8	48.8	451.10	466.43	4188.5	4141.4
PP	HO	20.8	21.2	432.31	448.57	45.7	46.2	411.43	420.76	3694.2	3940.6
	HE	18.7	19.0	359.53	392.65	41.9	43.2	336.17	374.48	2952.2	3409.2
	CO	20.0	20.4	412.86	445.54	44.7	45.6	397.60	414.09	3583.7	3473.8
PV	HO	19.8	20.1	410.08	419.63	44.2	43.8	379.36	387.70	3352.4	3463.6
	HE	18.4	18.6	290.08	318.45	39.6	38.8	272.22	295.98	2478.9	2692.4
	CO	21.8	22.5	512.31	558.66	48.1	49.2	453.96	494.86	4516.2	4928.8
PPV	HO	21.1	21.3	458.53	485.74	45.9	47.2	417.75	451.42	3825.5	4036.0
	HE	19.1	19.6	400.08	397.35	43.1	43.6	375.01	375.11	3231.1	3445.4
LSD 5%		1.4	1.9	69.25	97.44	4.6	6.3	62.30	89.33	633.9	972.8

FW*: Fresh weight PP: Peat moss:Perlite (1:1,v/v) PV: Peat moss:Vermiculite (1:1,v/v) PPV: Peat moss:Perlite:Vermiculite (1:1:1, v:v:v)
CO: Cooper HO: Hoagland HE: Hewitt

Outer leaves chemical composition:

The influence of substrate mixes (PP, PV and PPV), nutrient solutions (CO, HO and HE) and their interactions on photosynthetic pigments (Chl. a, b and carotenoids), and N, P and K of head lettuce fresh and dry outer leaves, consecutively, shown in Table (3). Data obtained demonstrate that the PPV mixture significantly affected all previous parameters as compared with the mixture of PV in both seasons, without significant differences between PPV and PP mixtures in these two growing seasons.

Pertaining the impact of nutrient solutions, data presented in the same table clearly indicated that both CO and HO ones had gave significant increases for the former parameters compared to the HE nutrient solution in both successive seasons. The highest values in this respect were obtained with CO nutrient solution, while the lowest values were registered with HE one.

The different interaction effects between growing media mixtures and nutrient solutions on all the forecited characters of head lettuce leaves are listed in Table (3). Most above tested interaction treatments gave high means as compared to the interaction treatment of PV + HE through two seasons. Since the combination treatment of PPV mixture + CO nutrient solution achieved significant increases for all studied parameters over combination treatment of PV mixture + HE nutrient solution in the first and second season in this connection. Whereas, the rest interaction treatments recorded means between these two extremes.

Heads yield components and its physical quality:

Data tabulated in Table (4) illustrate the effect of substrate mixtures, nutrient solutions and their interactions on head lettuce yield components (head and edible head FW, head yield/PVC P unit and head yield/fed) and its physical quality (Edible head diameter and compactness). Data presented in Table (4) and shown in figure (4: A-B) pointed out that all previous characters significantly influenced by all growing media mixtures used. Since PPV mixture followed by PP one had gave significant increases over PV mixture in both season without significant differences between PPV and PP mixtures in the first and second seasons. The highest values in this respect were obtained with PPV treatment, while the lowest values were attained with PV treatment.

Concerning the impact of nutrient solutions (i.e., CO, HO and HE), data shown in Table (4) also indicate that all above mentioned characters had been affected significantly by all nutrient solutions employed. As, CO solution treatment followed by HO one achieved significant increments for all studied characters as compared with HE solution treatment in two growing seasons. In this concern, the CO solution treatment gave the maximum records for all mentioned traits in the two successive seasons, whereas the minimum records were registered with HE solution treatment.

Regarding the effect of combination treatments, data given in the same table demonstrate that the aforementioned parameters significantly had been influenced by most combination treatments in both seasons. In this regard, the interaction treatment of PPV + CO, followed by PP + CO treatment and PPV + HO one attained significant increases for all forecited parameters over combination treatment of PV mixture + HE nutrient solution in both seasons. The rest combination treatments gave means between these two extremes.

Table 3. Effect of different substrate mixtures, nutrient solutions and their interactions on photosynthetic pigments, N, P and K of outer leaves of soilless cultured head lettuce during 1st and 2nd seasons after 65 days from transplanting.

Characters		Chl. a(mg/100g FW*)		Chl. b(mg/100gFW*)		Total carotenoids(mg/100gFW*)		N (%)		P (%)		K (%)	
Treatments		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Substrate mixtures													
PP		61.6	62.6	36.0	36.9	24.3	25.0	4.38	4.58	0.507	0.531	4.45	5.10
PV		57.9	58.3	32.5	33.2	21.8	22.1	3.98	4.23	0.463	0.497	4.01	4.71
PPV		64.9	66.4	38.4	38.9	25.4	26.2	4.53	4.73	0.543	0.550	4.57	5.41
LSD 5%		6.5	7.3	4.4	4.6	3.5	4.0	0.36	0.32	0.059	0.028	0.38	0.37
Nutrient solutions													
CO		68.1	69.8	40.1	40.9	26.5	27.1	4.62	4.85	0.559	0.564	4.80	5.73
HO		63.4	64.5	37.1	37.9	24.8	25.4	4.41	4.69	0.517	0.538	4.36	5.17
HE		52.8	53.0	29.6	30.1	20.2	20.8	3.87	4.00	0.438	0.475	3.87	4.32
LSD 5%		8.5	5.8	4.7	4.6	2.9	2.2	0.37	0.34	0.053	0.033	0.44	0.41
Interaction between substrate mixtures and nutrient solutions													
PP	CO	67.3	68.9	41.2	42.6	27.1	27.9	4.72	4.92	0.573	0.578	4.98	5.84
	HO	64.2	65.3	37.9	38.5	25.3	25.8	4.38	4.70	0.511	0.536	4.43	5.23
	HE	53.4	53.7	28.9	29.6	20.6	21.2	4.03	4.11	0.437	0.481	3.93	4.24
PV	CO	63.8	63.6	36.3	36.9	24.7	24.3	4.30	4.64	0.496	0.524	4.22	5.12
	HO	59.7	61.9	34.4	35.6	22.9	23.4	4.22	4.53	0.488	0.512	4.12	4.99
	HE	50.1	49.4	26.8	27.1	17.9	18.6	3.41	3.51	0.404	0.454	3.69	4.03
PPV	CO	73.3	76.8	42.9	43.1	27.8	28.9	4.84	4.98	0.608	0.592	5.21	6.23
	HO	66.5	66.2	39.1	39.8	26.3	27.0	4.60	4.85	0.550	0.567	4.52	5.29
	HE	54.8	56.1	33.2	33.7	22.0	22.8	4.17	4.37	0.471	0.491	3.99	4.70
LSD 5%		13.6	11.0	7.9	8.0	5.4	5.1	0.64	0.58	0.095	0.054	0.72	0.68

PP: Peat moss: Perlite (1:1,v/v) PV: Peat moss:Vermiculite (1:1,v/v) PPV: Peat moss:Perlite:Vermiculite (1:1:1, v:v:v)CO: Cooper HO: Hoagland HE: Hewitt

Table 4. Effect of different substrate mixtures, nutrient solutions and their interactions on heads yield components and their physical quality of soilless cultured head lettuce during 1st and 2nd seasons after 65 days from transplanting.

Characters		Head FW* (g/ plant)		Edible head FW* (g/ plant)		Edible headdiameter (cm/plant)		Edible head compactness rate		Head yield /PVC P unit(kg)		Head yield/fed(ton)	
Treatments		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Growing media mixtures													
PP		402.74	437.92	276.41	304.09	11.5	11.9	1.73	1.70	43.496	47.295	30.447	33.106
PV		350.34	367.94	258.47	258.42	10.4	10.6	1.36	1.46	37.837	39.738	26.486	27.817
PPV		430.02	452.21	306.27	324.03	12.1	12.2	1.87	1.73	46.443	48.839	32.510	34.187
LSD 5%		39.80	61.04	31.26	48.28	0.7	0.7	0.34	0.23	4.298	6.593	3.008	4.615
Nutrient solutions													
CO		448.28	484.26	316.06	336.04	12.4	12.7	1.89	1.83	48.414	52.300	33.890	36.610
HO		408.20	429.00	297.19	314.75	11.8	11.0	1.73	1.70	44.086	46.332	30.860	32.432
HE		326.62	344.82	227.91	235.75	9.8	10.0	1.34	1.35	35.276	37.241	24.693	26.068
LSD 5%		38.12	54.91	32.76	45.59	0.6	0.6	0.32	0.41	4.116	5.931	2.882	4.151
Interaction between growing media mixtures and nutrient solutions													
PP	CO	470.63	516.49	329.00	361.10	12.7	13.1	1.97	1.92	50.828	55.781	35.579	39.046
	HO	404.69	430.61	271.24	308.10	11.9	12.3	1.88	1.85	43.707	46.506	30.595	32.554
	HE	332.90	366.65	229.00	243.08	9.9	10.1	1.34	1.33	35.954	39.598	25.167	27.719
PV	CO	397.38	416.74	283.47	284.09	11.1	11.6	1.57	1.62	42.917	45.008	30.042	31.505
	HO	380.16	388.64	287.92	279.07	10.8	10.9	1.35	1.53	41.057	41.973	28.740	29.381
	HE	273.48	298.46	204.03	212.09	9.1	9.3	1.16	1.23	29.536	32.234	20.675	22.563
PPV	CO	476.82	519.54	335.70	362.94	13.4	13.3	2.13	1.96	51.497	56.110	36.048	39.277
	HO	439.75	467.75	332.42	357.09	12.7	12.7	1.98	1.72	47.494	50.517	33.245	35.362
	HE	373.49	369.35	250.70	252.07	10.2	10.6	1.52	1.50	40.337	39.890	28.236	27.923
LSD 5%		66.98	98.64	55.87	80.43	1.1	1.1	0.56	0.62	7.234	10.653	5.064	7.457

***FW: Fresh weight PVC P unit: poly vinyl chloride pipes unit PP: Peat moss: Perlite (1:1, v/v) PV: Peat moss: Vermiculite (1:1, v / v) PPV: Peat moss: Perlite: Vermiculite (1:1:1, v:v:v) CO: Cooper HO: Hoagland HE: Hewitt**

(A) (B)

Figure 4(A-B). A general view of the stages of plant growth; (A) growth development of head lettuce plants in growth units after 45 days of transplantation, (B) growth development of head lettuce plants in growth units after 60 days of transplantation.

Edible heads chemical quality:

Data presented in both Tables (5 and 6) indicate the influence of substrate mixtures (PP, PV and PPV), nutrient solutions (CO, HO and HE) and their interactions on fresh edible head chemical quality parameters (VC, TSS and TA), dry edible head ones (Protein %, Carbohydrate % and NO_3 content) and dry matter % of outer and inner leaves of lettuce.

A glance to data in Tables (5 and 6) conclude that most forecited parameters, except NO_3 content in the first season only, had significantly been affected by different substrate mixture treatments. Since, the best values were achieved with PPV mixture and vice versa with PV mixture in both seasons.

Seeing to data shown in the same aforementioned two tables, observe that the nutrient solutions of CO and HO gave significant values for all previous parameters as compared with the HE one in both seasons. The best means in this connection were attained with CO treatment and conversely for HE treatment in two growing seasons.

With relation to the effect of interaction treatments, data presented in both Tables (5&6) elucidate that all former characters had been affected by all different treatments as compared with the combination treatment of PV mixture + HE nutrient solution in both successive seasons. Since, the best significant values were obtained with the interaction treatment of PPV mixture + CO nutrient solution, while the less significant values were registered with PV mixture + HE nutrient solution treatment in these two consecutive seasons.

Table 5. Effect of different growing media mixtures, nutrient solutions and their interaction on fresh edible head VC, TSS and TA contents of soilless cultured head lettuce during 1st and 2nd seasons after 65 days from transplanting.

Characters		VC (mg/100g FW*)		TSS (%)		TA (%)	
Treatments		1st season	2nd season	1st season	2nd season	1st season	2nd season
Substrate mixtures							
PP		3.9	4.0	5.7	5.8	0.21	0.19
PV		3.3	3.2	4.7	4.8	0.49	0.44
PPV		4.2	4.5	6.1	6.2	0.34	0.29
LSD 5%		0.6	0.8	0.1	0.1	0.11	0.04
Nutrient solutions							
CO		4.6	4.8	6.6	6.8	0.31	0.27
HO		4.0	4.0	5.4	5.5	0.35	0.31
HE		2.9	2.9	4.5	4.6	0.39	0.34
LSD 5%		0.5	0.5	0.1	0.1	0.07	0.06
Interaction between substrate mixtures and nutrient solutions							
PP	CO	4.6	5.0	6.9	7.0	0.18	0.16
	HO	4.1	4.1	5.5	5.5	0.21	0.18
	HE	3.0	2.9	4.7	4.9	0.25	0.23
PV	CO	3.7	3.7	5.3	5.4	0.45	0.41
	HO	3.6	3.3	5.0	5.2	0.49	0.45
	HE	2.5	2.5	3.8	3.9	0.52	0.45
PPV	CO	5.4	5.8	7.7	7.9	0.29	0.25
	HO	4.1	4.6	5.8	5.9	0.35	0.29
	HE	3.2	3.2	4.9	5.0	0.39	0.33
LSD 5%		0.9	1.1	0.2	0.2	0.15	0.09

PP: Peat moss:Perlite (1:1,v/v) PV: Peat moss:Vermiculite (1:1,v/v) PPV: Peat moss:Perlite:Vermiculite (1:1:1, v:v:v)CO: Cooper HO: Hoagland HE: Hewitt VC: Vitamin C TA: Total acidity

Table 6. Effect of different substrate mixtures, nutrient solutions and their interactions on dry matter of outer and inner leaves and dry edible head lettuce protein, carbohydrate and NO_3 contents of soilless cultured head lettuce during 1st and 2nd seasons after 65 days from transplanting.

Characters		Dry matter (%) Outer leaves		Dry matter (%) Inner leaves		Protein (%)		Carbohydrate (%)		Edible head NO_3^* (mg/kgDW**)	
Treatments		1stseason	2ndseason	1stseason	2ndseason	1stseason	2ndseason	1stseason	2ndseason	1stSeason	2ndseason
Substrate mixtures											
PP		4.85	4.96	3.64	3.82	22.7	26.0	13.71	14.29	101.03	104.88
PV		4.52	4.60	3.42	3.66	21.2	22.1	13.25	13.28	108.88	111.74
PPV		5.03	5.13	3.77	4.00	25.2	27.7	14.07	14.66	96.10	100.25
LSD 5%		0.34	0.40	0.16	0.03	2.6	4.1	0.57	0.91	14.87	5.67
Nutrient solutions											
CO		5.12	5.20	3.98	4.09	26.0	28.7	14.36	14.83	90.13	95.43
HO		4.97	5.03	3.62	3.82	24.4	26.9	13.61	14.36	99.14	100.69
HE		4.31	4.45	3.22	3.56	18.7	20.1	13.07	13.05	116.74	120.76
LSD 5%		0.19	0.32	0.09	0.08	2.7	3.9	0.62	1.00	9.70	6.61
Interaction between substrate mixtures and nutrient solutions											
PP	CO	5.25	5.29	4.00	4.09	27.0	30.8	14.37	14.96	88.39	94.33
	HO	5.04	5.10	3.71	3.82	22.3	26.3	13.63	14.69	98.81	100.50
	HE	4.24	4.48	3.20	3.54	18.8	20.7	13.13	13.22	115.89	119.81
PV	CO	4.79	4.88	3.66	3.79	23.3	24.2	13.57	13.74	100.30	102.79
	HO	4.73	4.79	3.47	3.68	23.6	23.8	13.46	13.48	103.33	105.23
	HE	4.05	4.14	3.12	3.51	16.7	18.1	12.74	12.63	123.01	127.21
PPV	CO	5.31	5.44	4.28	4.40	27.6	31.0	15.13	15.79	81.69	89.15
	HO	5.14	5.21	3.69	3.96	27.3	30.5	13.74	14.90	95.29	96.34
	HE	4.63	4.75	3.33	3.64	20.6	21.5	13.74	13.30	111.33	115.27
LSD 5%		0.43	0.59	0.20	0.12	4.6	6.9	1.04	1.67	20.20	10.93

PP: Peat moss:Perlite (1:1,v/v) PV: Peat moss:Vermiculite (1:1,v/v) PPV: Peat moss:Perlite:Vermiculite (1:1:1, v:v:v)CO: Cooper HO: Hoagland HE: Hewitt NO3*: Nitrate DW: Dry weight**

The cost analysis of both PV and diesel systems.

The life cycle costs of PV, and diesel-powered systems as shown in Table (7) were compared. In each system, the cost of a kilowatt of energy was calculated, and this will tell us which system is economically viable. Knowing that the common market prices in 2020 was employed. The total cost in the PV, and diesel-operated systems were 2.49, and 12.84 LE/h. Also, the cost of producing energy (1KW.h) reaches 1.33, and 4.20 LE/KW.h, and the operating cost (LE/m^3) reaches 0.31, and 0.97 LE/m^3, consecutively. Similar comparison results were stated by Al-Awady *et al*. (2015), Soliman *et al*. (2017), Bhattacharjee *et al*. (2019), Tayel *et al*. (2019) and Ibraheam and Aslan (2023).

Table 7. The cost analysis of PV and diesel systems.

Term	PV system	Diesel system
Price of system (P) LE	12100	15330
Yearly working hours (h)	2190	2190
Life expectancy (e), year	25	10
Interest rate (i) %	0.12	0.12
Taxes (t) %	0.10	0.20
Maintenance (r)	0.10	0.20
Fuel cost (w) LE/h	0	7.25
Monthly wages (m) LE/month	150	300
Monthly average working hours	180	180

Discussion

It is quite clear from the obtained results related to the effect of soilless substrate mixtures, nutrient solutions and their interactions on the growth and field performance parameters of soilless cultured head lettuce plants that there are generally significant influences of these studied factors on all of the determined traits.

Respecting the influence of soilless substrate mixtures, the acquired results go in line with the findings of Schmilewski (2009), Bhat *et al*. (2013), Makhadmeh *et al.* (2017), Saurabh *et al*. (2019), Hamaiel *et al*. (2020), El-Biyaly (2021), Uy *et al.* (2021), Nasih *et al*. (2022) on lettuce and Gaikwad *et al.* (2020) on spinach. The stimulatory effect of substrate mixture may be due to that mixing coarse mineral substances such as perlite and vermiculite with organic ones like peat moss has leads to better growth and higher productivity probably owing to increasing water-holding capacity and better ventilation of the satisfactory loose substrate mixture used (Gao *et al*., 2010), thus promotes vigorous and efficient root formation and growth which may allow plants to access important nutrients, which in turn could allow rapid and strong growth of plant foliage (as shown in table 2) and consequently increases yield (as shown in table 4) and quality (as shown in tables 5&6) (Olle *et al*., 2012) of the obtained head lettuce plants grown in A-shaped plastic PVC pipe units of substrate cultures.

Concerning the impact of nutrient solutions, the resultant data are in consistent with those obtained by Genuncio *et al*. (2012), Kim *et al*. (2016), Santiago (2019), Ahmed *et al*. (2021), El-Biyaly (2021), Borres *et al*. (2022), Kilic (2022), Ramos (2022), Solis and Magaret (2022), Salama (2023), Solis and Gabutan (2023) on lettuce. The positive increases in growth, yield and quality traits of soilless head lettuce plants related to different nutrient solutions used can be attributed to the difference in the concentration of essential nutrients between those solutions. As Cooper's nutrient solution contains the highest and most appropriate concentrations of these essential nutrients, followed by Hoagland's solution, then Hewitt solution (as shown in table 1), which contains low and unbalanced essential nutrient ratios compared to Cooper and Hoagland's solutions, respectively. Therefore, it is possible to explain the desired results obtained for all tested parameters of head lettuce resulting from the use of Cooper's solution in particular because it contains a balanced concentrations of the basic nutrients, which together represent optimal proportions that contribute fundamentally to stimulating the basic physiological and biochemical processes in the plants, resulting in activate the biosynthesis of many important organic compounds such as nucleic acids, amino acids, proteins, carbohydrates, vitamins, enzymes, photosynthetic pigments, etc., which are considered essential components for high head lettuce growth, productivity and quality.

CONCLUSION

Concerning the obtained results, it could be concluded that using the combination treatment of PPV mixture + CO nutrient solution is considered the best treatment to achieve a maximum growth and productivity of soilless cultured head lettuce cv. Big Bell with the use of cheap and safe renewable solar energy to operate the fertigation system, especially in remote areas.

REFERENCES

A.O.A.C. (1990). Official methods of analysis.15th ed., Association of Official Analytical Chemists, International, Arlington, Virginia, USA.

Ahmed, Z. F. R.; A. K. H. Alnuaimi, A. Askri and N. Tzortzakis (2021). Evaluation of lettuce (*Lactuca sativa* L.) production under hydroponic system: nutrient solution derived from fish waste vs. inorganic nutrient solution. Hort., 7 (9): 1-12.

Al-Awady, M. N.; M. F. Abdel-Salam, H. A. Mahdy and A. A. Amer (2015). Development of water culture system depending on renewable energy to suit remote areas. Misr J. Agric. Eng., 32 (3): 1313-1342.

Awady, M. N. (1978). Tractor and Farm Machinery. Txt bk., Col. Ag., Ain Shams Univ., 146–167.

Bhat, N. R.; M. S. Suleiman, B. Thomas, V. S. Lekha, P. George and I. S. Ali (2013). Growing substrates for organic lettuce production in Kuwait. World J. Agric. Sci., 9 (2): 143-147.

Bhattacharjee, B., A. Chakrabarti and P. K. Sadhu (2019). Solar photovoltaic integrated pump for advanced irrigation system. Int. J. Innovative Tech. and Exploring Eng., 8 (8): 3246-3250.

Borres E. C., E. B. Basulgan and R. M. L. Dalanon (2022). Potentialities of lettuce (*Lactuca Sativa* L) in hydroponics system under simple nutrient addition program (SNAP), J. Education Management and Development Studies, 2 (1): 76-85.

Dutta, D.; V. Sharma, S. Guria, S. Chakraborty, S. Sarveswaran, D. Harshavardhan, P. Roy, S. Nandi, A. Thakur, S. Kumar, S. S. Sonar, N. Khadka, M. Lakshmi and Md. N. S. Shah (2023). Optimizing plant growth and crop productivity through hydroponics technique for sustainable agriculture: a review. Int. J Environ. and Climate Change, 13 (9): 933-940.

El-Biyaly, H. A. M. (2021). Studies on lettuce growth, productivity and quality using soilless culture system. MSc. Thesis, Fac. Agric., Damietta Univ., Damietta, Egypt.

FAO (2023). Food and Agriculture Organization of the United Nations, FAOSTAT, FAO Statistic Division, March 24, 2023.

Gaikwad, D. J., S. Priyadarsini and B. Mallick (2020). Effects of different hydroponics systems and growing media on physiological parameters of spinach. Int. J. Current Micro. and Applied Sci., 9 (5): 1409-1414.

Gao, H. B.; T. J. Zhang, G. Y. Lv, G. H. Zhang, X. L. Wu. J. R. Li and B. B. Gong (2010). Effects of different compound substrates on growth, yield and fruit quality of cucumber. Acta Hort., 856, 173-180.

Genuncio, G. C; M. Gomes, A. C. Ferrari, N. Majerowicz and E. Zonta (2012). Hydroponic lettuce production in different concentrations and flow rates of nutrient solution. Hort. Bras., 30 (3): 526-530.

Gomez, K. A. and A. A. Gomez (1984). "Statistical procedures for agricultural research". John Wiley & Sons Inc., New York, 2nd ed., 68 p.

Hamaiel, A. F., W. A. El-Saady and Hanan A. M. El-Biyaly (2020). Effect of substrate culture system and growing media type on growth, yield and quality of soilless cultured lettuce (cv. Green Star). J. Plant Production, Mansoura Univ., 11 (12): 1427-1434.

IBraheam, E. H. and S. R. Aslan (2023). Solar photovoltaic water pumping system approach for electricity generation and irrigation: Review. Diagnostyka, 24 (2): 1-7.

Kilic, C. C. (2022). Effect of nitrogen and planting dates on yield and yield components of head lettuce grown in soilless culture. J. Plant Nutrition, 1-15.

Kim, M. J.; Y. Moon, J. Tou, B. Mou and N. Waterland (2016). Nutritional value, bioactive compounds and health benefits of lettuce (*Lactuca sativa* L.): study review. J. Food Composition and Analysis, 49, 19-34.

Makhadmeh, I. M.; A. R. Al Tawaha, P. Edaroyati, G. Al-Karaki and S. A. Hassan (2017). Effects of different growth media and planting densities on growth of lettuce grown in a closed soilless system." Res. on Crops, 18 (2): 294-98.

Matheswaran, A.; C. Ganesh Babu, K. Lakshmi, P. Sivaranjani, R. K. Dhanuja and M. N. Shree (2021). Performance evaluation of standalone solar powered water irrigation system using DC pump. IOP Conf. Series: Materials Sci. and Eng., 1084 012108, 1-10.

Murray, J., G. Basset and G. Sanodya (2021). Nutritional benefits of lettuce consumed at recommended portion sizes. Univ. Florida Coop Ext. Serv. EDIS Pub. HS1416, https://doi.org/10.32473/edis-hs1416-2021.

Nasih, H. B., H. B. Abdulrahman and J. Z. Ghassan (2022). Effect of agricultural medium in hydroponic system on growth and yield of two hybrids of lettuce (*Lactuca sativa* L.). IOP Conf. Series, Earth and Environ. Sci., 1-

Ogbomo, O. O.; E. H. Amalu, N. N. Ekere and P. O. Olagbegi (2017). A review of photovoltaic module technologies for increased performance in tropical climate. Renewable and Sustainable Energy Reviews, 75, 1225-1238.

Olle, M., M. Ngouajioand and A. Siomos (2012). Vegetable quality and productivity as influenced by growing medium: Areview. Agric., 99 (4): 399-408.

Praveen, K. S.; N. Senthilkumar, P. Poonkodi and M. Thiruppathi (2022). Soilless substrates on vegetable production: A review. Int. J. Creative Res. Thoughts, 10 (3): 949-959.

Ramos, A. P. (2022). Hydroponic treatment of lettuce (Lactuca sativa) on different fertigations. Int. J. Farm Sci., 12 (2): 13-18.Riad, G.; A. Ghoname, A. Ahmed, M. Abd El- Baky and A. Hegazi (2009). Cabbage nutritional quality as influenced by planting density and nitrogen fertilization. Fruit, Vegetable and Cereal Sci. and Bio., 3 (1): 68-74.

Salama, Y. A. M. (2023). Effect of some organic treatments on the tolerance of high temperature cabotta lettuce plants under the hydroponics cultivation system. Egyptian J. Desert Res., 73 (1): 65-84.

Salem, Enas, L. A. (2016). Development the performance of the photovoltaic cells system and their applications in youth graduates farms. Ph. D. Thesis, Fac. Agric., Mansoura Univ., Mansoura, Egypt.

Santiago, R. T. (2019). Performance of hydroponic lettuce using organic medium solutions. IAMURE Inter.J. Ecology and Conservation, 29 (1): https://ejournals.ph/article.php?id=14897.

Saurabh, A., A. Sharma and S. Singh (2019). A review on effect of different soil less growing media on vegetable production. 2nd International Conference "food security, nutrition and sustainable agriculture - emerging technologies", 215-219.

Schmilewski, G. (2009). Growing medium constituents used in the EU. Acta Hort., 819, 33-45.

Shepovalova, O. V., A. T. Belenov and S. V. Chirkov (2020). Review of photovoltaic water pumping system research. Energy Reports, 6: 306–324.

Snedecor, G. W. and W. G. Cochran (1989). "Statistical methods". 8th ed., Iowa State Univ., Press, Ames Iowa, USA.

Soliman, A. W., A. H. Nassar and A. M. Sattar (2017). Cost analysis for irrigation projects using solar energy in Egypt. Int. J. Sci. and Eng. Res., 8 (9): 1168-1176.

Solis, E. S. and J. Magaret (2022). Lettuce (*Lactuca sativa* L. var. Rincon) production using organic nutrient solution under hydroponics system. American J. Agric.Sci. Eng., and Tech., 6 (3): 24-32.

Solis, E. S. and J. U. Gabutan (2023). Hydroponic lettuce (*lactuca sativa* l. var. *lalique*) production using commercially available nutrient solutions. Int. J. Agric. and Environ. Res., 9 (3): 330-341.

Soylemez, S. (2021). The impact of different growth media and ammonium-nitrate ratio on yield and nitrate accumulation in lettuce (*Lactuca sativa* var. *longifolia*). .Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 49 (4): 1-13.

Stojanovic, M.; S. Savic, A. Delcourt, J. L. Hilbert, P. Hance, J. D. Maksimovic and V. Maksimovic (2023). Phenolics and sesquiterpene lactones profile of red and green lettuce: combined effect of cultivar, microbiological fertiliser, and season. Plants, 12 (2616): 1-20.

Tayel, S. A.; A. M. Lithy, A. Hegazi and Y. F. El-Saadawi (2019). Performance evaluation of water pumping system powered by solar energy. Misr J. Agric. Eng., 36 (1): 283-302.

Thakulla, D.; B. Dunn, B. Hu, C. Goad and N. Maness (2021). Nutrient solution temperature affects growth and Brix parameters of seventeen lettuce cultivars grown in an NFT hydroponic system. Hort., 7 (9): 321-330.

Uy, M. M., F. M. Tomaneng and G.L. Seridon (2021). Evaluation of different growing substrates on lettuce (*Lactuca sativa*) under non - circulating hydroponic system. Int. J. Biosci.,18(1):93-101.

تأثير بيئات نمو ومحاليل مغذية متنوعة على نمو وإنتاجية خس الرؤوس المنزرع لاأرضياً مع استخدام الطاقة الشمسية لتشغيل نظام الرسمدة

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الملخص

أجريت هذه الدراسة بوحدة الزراعة بدون تربة، كلية الزراعة، جامعة المنصورة، مصر خلال الموسمين الشتويين المتتاليين لعامي 2021/2020 و 2022/2021 م، لدراسة تأثير ثلاثة مخاليط بيئات نمو صلبة هى البيت موس : البيرلايت 1:1 (PP)، البيت موس : الفيرميكيولايت 1:1 (PV) و البيت موس : البيرلايت : الفيرميكيولايت 1:1:1 (PPV)، وثلاثة محاليل مغذية متنوعة هى محاليل كوبر (CO)، هوجلاند (HO) و هويت (HE) وتفاعلاتها على إنتاجية وجودة خس الرؤوس صنف بيج بيل المنزرع لاأرضياً. أظهرت النتائج المتحصل عليها بوضوح أن جميع الصفات المختبرة للخس كصفات النمو الخضري (إرتفاع النبات، الوزن الطازج لكل من النمو الخضري والأوراق/نبات، وعدد الأوراق و المساحة الورقية/ نبات)، وتركيز صبغات التمثيل الضوئي (كلوروفيل أ، كلوروفيل ب و الكاروتينيدات) و (النسبة المئوية للنيتروجين، والفوسفور و البوتاسيوم) بأوراق الرأس الخارجية، ومحصول الرؤوس (الوزن الطازج للرأس كاملة، الوزن الطازج للرأس الصالحة للأكل ومحصول الرؤوس لكل من الوحدة الهرمية الشكل وكذلك للفدان)، وجودة الرأس الصالحة للأكل (محتوى فيتامين ج، والمواد الصلبة الذائبة والحموضة، والقطر ومعدل الإندماج)، ومحتوى البروتين والكربوهيدرات والنترات في المادة الجافة لأوراق الرأس الصالحة للأكل، قد تأثرت معنوياً بجميع العوامل المدروسة وتفاعلاتها. هذا ولقد تم تحقيق القيم المعنوية الأفضل لجميع الصفات المذكورة سابقاً مع مخلوط بيئات النمو الصلبة المكون من البيت موس : البيرلايت : الفيرميكيولايت 1:1:1 (PPV) ومحلول كوبر المغذي مقارنة بمخلوط بيئات النمو الصلبة المكون من البيت موس : الفيرميكيولايت 1:1 (PV) ومحلول هويت المغذي. لذلك، يمكن التوصية بأن مزارع البيئات الصلبة لنباتات خس الرؤوس في وحدات مواسير الـPVC هرمية الشكل المحتوية على مخلوط بيئات النمو الصلبة (PPV) والمغذاة بمحلول كوبر المغذي عبر نظام الرسمدة المدار بالطاقة الشمسية المتجددة، والرخيصة والصديقة للبيئة تعتبر الخيار الأمثل من أجل تحقيق نمو وأداء نباتي مُرْضٍ.