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Impact of eco-engineering systems on growth and productivity of basil (Ocimum basilicum L.)

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Abstract

The main aim of this study is to determine the favourable cultivation system and irrigation levels for cultivate basil plants at soilless technique. To achieve this, the effect of three different soilless cultivation systems (aeroponics, hydroponics, and substrates) and three different water discharges (3, 4, and 5 L h^{-1} $plant^{-1}$) on shoot and root lengths, stem diameter, and chlorophyll content during different growth periods (10, 20, 30, 40, and 50 days), also, fresh and dry mass, and fertilizer consumption rate (nitrogen, phosphorus, potassium, calcium, and magnesium) at the end of the growth phase (50 days) were studied. The experiments concluded that the best soilless cultivation system was the aeroponic system at a water flow rate of 4 L h^{-1} $plant^{-1}$, which achieved the longest vegetative group of 67.45 cm, the root group of 48.21 cm, the stem diameter of 3.7 mm, the chlorophyll in the leaves of 39.43 SPAD, the fresh mass of the vegetative group of 483.25 g, the dry mass of the vegetative group of 118.93 g, the fresh mass of the root group of 379.3 g, the dry mass of the root group of 103.45 g, and the consumption rate of fertilizer elements (nitrogen 723.64 mg, phosphorus 251.2 mg, potassium 754.29 mg, calcium 519.73 mg, and magnesium 223.66 mg).

Keywords: Aeroponic, Hydroponic, Substrate, plant properties, Nutrients uptake

1. Introduction

Basil is an aromatic herb, has many medical benefits. It is used as antioxidant. It is used as antioxidant and contains vitamins A and C. Also, it has as antiflamnatory effects and increases the immunity support. Basil is a good source of essential nutrients such as vitamin K, magnesium, calcium and manganese. It used as aid in digestion and reduce bloating [1]. Moreover, its extract and essential oil are widely used in the food industry as a flavoring agent [2]. Essential oils that extracted from the basil leaves are influenced by many factors such environmental and genetically conditions. The agricultural practices also affect essential oils. The environmental factors like temperature, light, RH, salinity and soil conditions [3, 4, 5, 6, 7]. Basil is an important economic crop used widely for both its culinary and medicinal uses. Farmers try to increase their benefits by increasing the yield extent the production season and introduced of basil cultivation in greenhouse to garneted getting yield during the whole season [8]. Also, it reduces stress when use it as herbal tea and improve overall well-being [9].

Soilless is a method of growing plants using mineral nutrient solution without soil. It could be practical with fewer pesticides, less land use, and reduce water consumption. Also, it optimizes the use of space, allowing greater crop density in small area. Also, the soilless cultures are the earliest growth and higher yield compared to traditional culture. Therefore, it is considered one of the promising solutions to climate change and its harmful effects on the productivity of traditional agriculture. Also, more equal supply of nutrient solution can be achieved and so more homogeneous crops can be obtained. In soilless systems the concentration and composition of mineral elements to be applied to crops can be adjusted at will, and pH and mineral composition of the solution are easily changeable. For this reason, shortage and excess of nutrients in the solution are apt to occur. In traditional agriculture, it takes a long time to grow seedlings, but soilless culture can save the time in the all processes in soilless culture [10, 11, 12, 13, 14]. But, we have to be careful, because the plants in system are susceptible to the light intensity variations and the time of exposure in addition to the nutrient concentrations [15, 16, 17].

Many researchers have investigated the plants grown in the soilless culture systems (SCS) such as [18,19,20,21,22] and they concluded that the yield of lettuce cultivated in tropical areas improved by 35 and 72% in Brazil and Myanmar, respectively. The water use efficiency increased also 7.7 and 2.7 times higher than that of the traditional soil system. The SCS can also influence the rooted cutting growth. Also, using the open-cycle drip system improved the commercial properties of the plants compared to the traditional, substrate and NFT. The water use efficiency increased as the water consumption increase compared to other systems. According to [23] the expressively system is the Nutrient Film technique (NFT) hydroponic on the EBB and soil-based systems for basil plants growth according plant properties. It achieve the tallest shoot and root, the biggest stem diameters and the best absorb the amount of nutrients and water quality. The root rot is the most common problem facing the soilless and hydroponic systems while is attributed to the low oxygen level in the nutrient solution, so that the suitable aeration is needed to face this problem. Therefore, this study was aimed to investigate the possibility of growing basil under three soilless systems.

2. Materials and methods

This study was conducted in the Fish Farms and Protected Houses Center, Faculty of Agriculture Moshtohor, Benha University, Egypt (latitude 30° 21` N and 31° 13` E). During the months of June, July and August, 2024. The soilless experimental setup as shown in Fig (1) consist of aeroponic system, hydroponic system, soilless substrate system, solution system and pumps.

- **Aeroponic system**

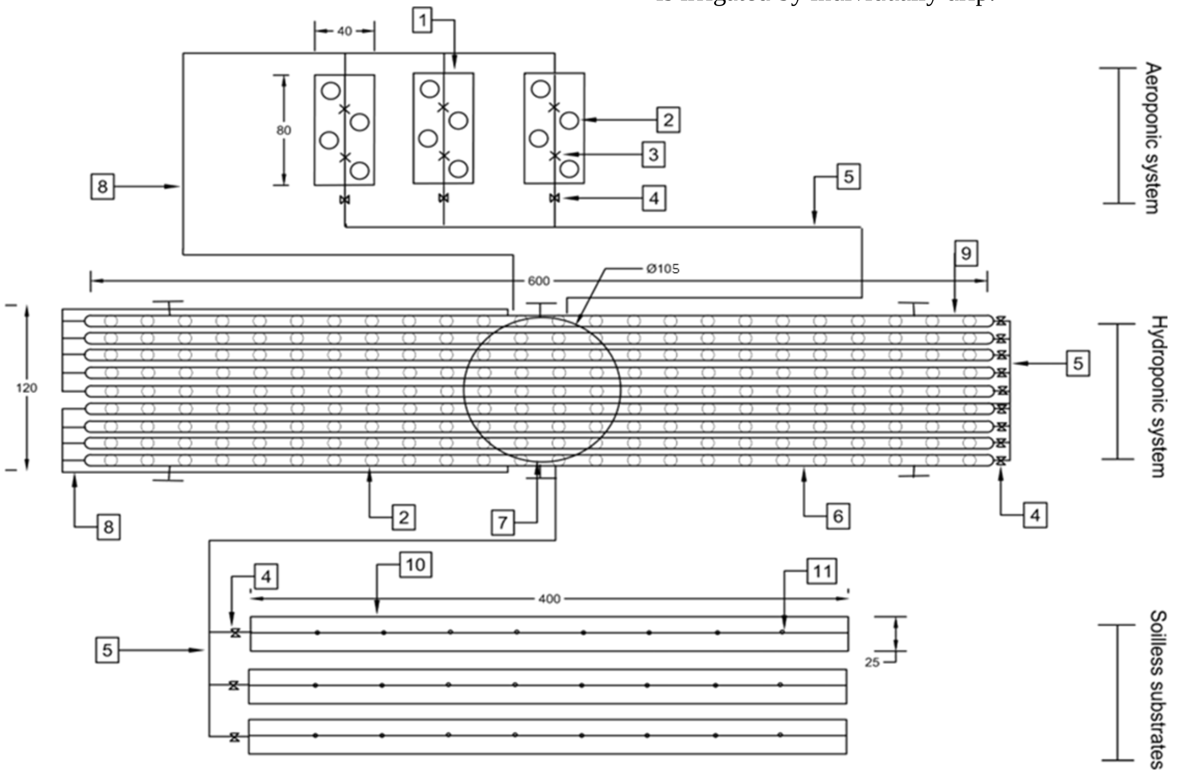
Aeroponic system (Fig. 2-A) made of three tanks (rectangular in shape), their dimensions are 80 cm long, 40 cm width and 50 cm height, where placed at 1.0 m above the ground. These tanks were covered with foam boards to be used in fixing the plants. Spray nozzles were fixed in the tank bottom.

- **Hydroponic system**

The hydroponic system with "A" shape (Fig. 2-B) consists of three stands made of iron. Dimensions of each stand are 1.2 m wide and 1.7 m high. Each A shape consists nine polyvinyl chloride (PVC) pipe, the dimensions of pipe are 110 mm in diameter and 6.0 m long. The slope of pipes was 2 %. Small tubes (16 mm) were used to provide tanks with solution in a closed system. There were three plants per meter giving a mean density of 9.0 plant m^{-2} for basil.

- **Soilless substrates**

Soilless substrates (Fig. 2-C) were placed in three rows (4 x 0.25 x 0.20 m). Each row made of polyethylene sheet is 1 mm thickness and it consists standard peatmoss + perlite + vermiculite (2:1:1). Basil plants were put on row with a drip irrigation system. There were three plants per meter giving a mean density of 9.0 plant m^{-2} for basil. Each plant is irrigated by individually drip.



1. Basil plants basin in the aeroponic system, 2. Plant holes, 3. Fog nozzle, 4. Water valve, 5. Flow pipe (16 mm), 6. PVC pipe (110mm), 7. Nutrient solution tank, 8. Outflow pipe, 9. Basil plants in the hydroponic system 10. Basil plants basin in the soilless substrate system, and 11. Drip irrigation.

Fig. (1): The soilless experimental setup (Dimensions: cm)

A- Aeroponic system B- Hydroponic system C- Substrate system

Fig. (2): The soilless experimental

Nutrient solution tank

The circular polyethylene tank of the nutrient solution system 1000liter capacity was used for collecting the drained solution by gravity from the ends of the three systems. The nutrient solutions were prepared manually by dissolving appropriate amounts of $Ca(NO_3)_2$, 236 g L^{-1}, KNO_3, 101 g L^{-1}, K_2SO_4, 115 g L^{-1}, KH_2PO_4, 136 g L^{-1}, $MgSO_4$ 246 g L^{-1} and chelates for trace elements as a solution in water (from the following ppm concentration are achieved in this formulation: N=210, P=31, K=234, Ca=200, Mg=48, S=64, Fe=14, Mn=0.5, Zn=0.05, Cu=0.02, B=0.5, Mo=0.01). pH and Electrical Conductivity (EC) were further adjusted to 6.5-7.0 and 1.4-1.8 dS m^{-1}, respectively, after salt addition. The average air ambient temperature was 25.97±4.37 °C and the average water temperature was 24.03±3.92 °C. The average relative humidity was 65.4% and the light intensity was 338.55±40.06 W m^{-2}.

Irrigation water and solution were supplied to plants from nutrient solution tank with the proper nutrient solution by 0.5 hp pump (Model First QB60 – Flow Rate 30 L min^{-1} – Head 25 m – Power 0.5 hp, made in China).

Basil plants

Basil (*Ocimum basilicum L.*) seedlings were grown in a peat moss which placed in plastic cups (7 cm diameter and 7 cm height) filled with peat moss. The cups were irrigated daily using water with nutrient solution. Basil seedlings were planted at 9 plant m^{-2} [24].

The studied variables include:

1- Three soilless systems are aeroponic "Sap", hydroponic "Shp" and substrate "Ss" systems
2- Three water flow rates "Fr" are 3, 4 and 5 L h^{-1} $plant^{-1}$.

The evaluation of plant growth and the quality of soilless systems the measurements were done every ten days include; shoot length, root length, (using by a tape meter ±1.0 mm), stem diameter (using by a digital vernier caliper ±0.01mm) and chlorophyll content (using a chlorophyll meter (Model Minolta SPAD-502 - Accuracy ± 1.0 SPAD unit, Japan)). While the fresh and dry masses of shoot and root weights were recorded at the end of experiment. Dry mass of the plants were measured by using oven dryer at 65 ºC until constant mass was reached. Macro elements were determined according to [25]**.** Nitrogen was measured according to [26]. Potassium, Photofatometer (Model Jenway PFP7 – Range 0 - 160 mmol L^{-1}, USA). was used to determined calcium and magnesium and phosphorus was measured colorimetrically following the [27] method.

The experiments lasted of 50 days "Gp". The design of experimental was a split-split plot with three replicates. The coefficient of variance, standard deviation, fit-curve and the regression analysis were done to define the best system under study.

3. Results and Discussion

3.1. Effect of the studied variables on basil shoots length

As illustrated in Fig (3) the relationship between the shoot length and growth period have a directly relationship. From the figure it can clear that, different irrigated-water flow rate and different soilless systems showed that regarding to the increase of growth period from 10 to 50 days the shoot length increase from 15.47 to 63.03; 21.09 to 67.45 and 17.54 to 62.14 cm respectively at water flow rate of 3, 4, and 5 L h^{-1} $plant^{-1}$ at cultivation in "Sap" system. At "Shp" system and the corresponding above growth period the shoot length increased from 14.48 to 58.75, 21.13 to 61.68 and 18.86 to 57.99 cm respectively at water flow rate of 3, 4 and 5 L h^{-1} $plant^{-1}$. However at substrate system and the increasing in growth period from 10 to 50 days, the shoot length of plants were increased from 13.43 to 54.44, 20.20 to 59.03 and 16.54 to 54.47 cm respectively at 3, 4 and 5 L h^{-1} $plant^{-1}$ of water flow rate. These previous results were agreement with the results found by [24]**.**

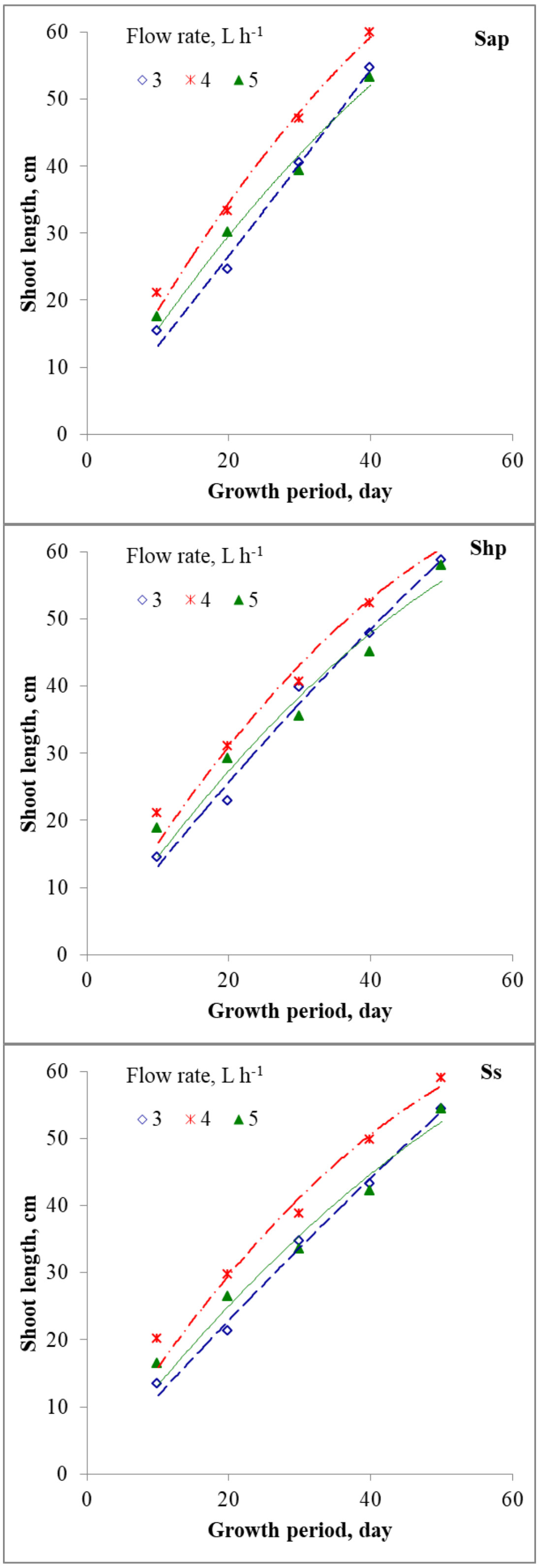


Fig. (3): The relationship between shoot length and growth period at different irrigated-water flow rate and different soilless systems.

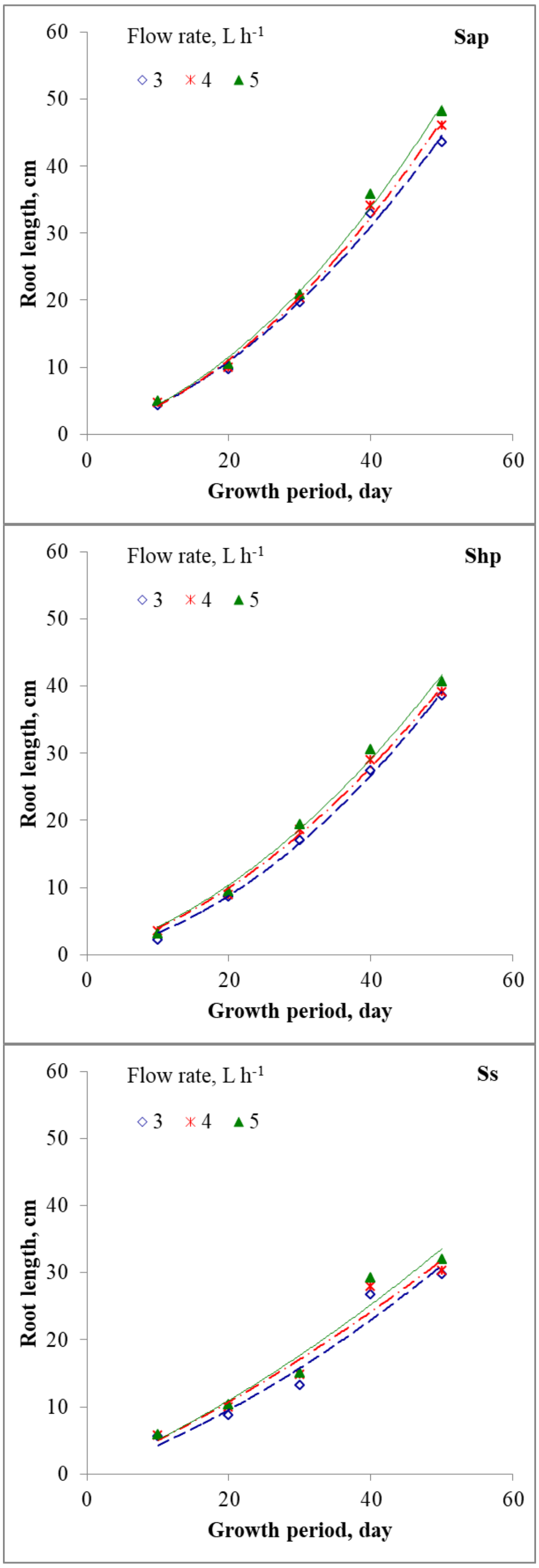


Fig. (4): The relationship between root length and growth period at different irrigated-water flow rate and different soilless systems.

The results also indicate that, the shoot of the basil plants grown in aeroponic system were taller than those of hydroponic system and substrate system during the experimental growth period. It could be seen that the highest value of shoot length of basil plants was 67.45 cm for aeroponic system at water flow rate of 4 L h^{-1} $plant^{-1}$ in the end of growth period. Meanwhile, the lowest value of shoot length of basil plants was about 54.44 cm, found at substrate system and growth period of 50 days. These results which is agreed with those obtained by [28, 29].

From the data it can clear that the highest percentage of shoot lengths were 26.65, 31.47 and 33.51% respectively at soilless systems of “Sap”, “Shp” and “Ss” at growing period of 10 days. Whereas, at evaluate the all soilless system at the end of the growth period, the average of shoot length were 64.21, 59.47 and 55.98 cm respectively at “Sap”, “Shp” and “Ss” systems. These results mean that the highest shoot length achieved at the end of growth period in “Sap” system. These results due to the seedlings' rapid adaptation to continued growth at the beginning of the planting period due to the availability of suitable environmental conditions. Thus the maximum percentage of shoot lengths were 75.45, 75.35 and 75.33% respectively at soilless systems of “Sap”, “Shp” and “Ss” at water flow rate of 3 L h^{-1} $plant^{-1}$. These results due to providing sufficient air for plant roots to breathe at an irrigation rate of 3 L h^{-1} $plant^{-1}$ compared to other rates, which led to an increase in the vegetative mass.

The multiple regression analysis of the soilless systems (Ss), growth periods (Gp) and water flow rates (Fr) had a highly significant linear relationship with the shoot length (Lsh). The best fit equation to explain the correlation between the shoot length (Lsh) and each of studied variables could be indicated as follows:

Lsh = 11.170 - 3.055Ss + 1.067Gp + 0.430Fr with R^2 = 0.9584

Moreover, the regression analysis showed that the shoot length (Lsh) was inversely proportional to the soilless systems (Ss) and a directly proportion to the growth period (Gp) and water flow rate (Fr). However, Fig (5) shows the relationship between the predicted and the actual shoot length of basil plants with the coefficient of determination of r^2 = 0.9584.

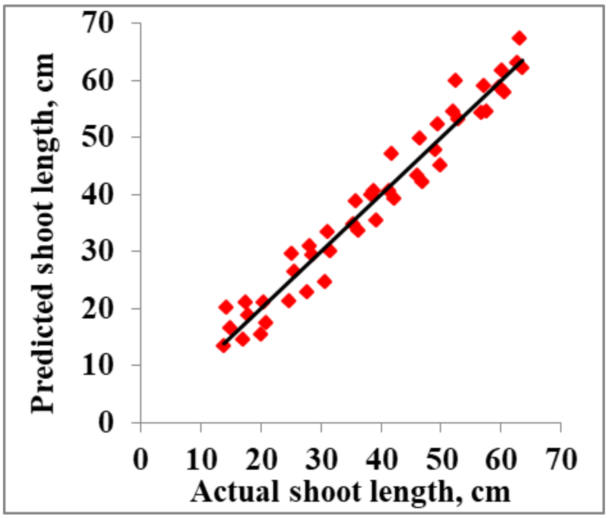


Fig. (5): The relationship between the predicted and the actual shoot length of basil plants

3.2. Effect of the studied variables on basil roots length

Fig (4) shows the relationship between the root length and growth period have a directly relationship. From the figure it can clear that, different irrigated-water flow rate and different soilless systems showed that regarding to the increase of growth period from 10 to 50 days the root length increase from 4.35 to 43.55, 4.67 to 46.00 and 4.91 to 48.21 cm respectively at 3, 4 and 5 L.h^{-1} $plant^{-1}$ of water flow rate at cultivation in “Sap” system. Furthermore, in “Shp” system when the plant age increased from 10 to 50 days, the root length increased from 2.20 to 38.59, 3.51 to 39.14 and 3.12 to 40.72 cm respectively at 3, 4 and 5 L h^{-1} $plant^{-1}$ of water flow rate. Moreover in “Ss” system and at the same growth periods, the root length of basil increased from 5.61 to 29.72, 5.78 to 30.36 and 5.90 to 32.05 cm respectively at water flow rate of 3, 4 and 5 L.h^{-1} $plant^{-1}$. The results of measurements of root of the basil plants grown in aeroponic system were taller than those of hydroponic system and substrate systems during the experimental period. It could be seen that the highest value of root length of basil plants was 48.21 cm for aeroponic system at 5 L h^{-1} $plant^{-1}$ flow rate at the end of growth period, while, the lowest value of root length of basil plants was 29.72 cm was found with substrate system at the end of growth period. The root length for basil plants grown in aeroponic system were 1.47, 1.52 and 1.50 times taller than those grown in substrate system respectively at water flow rate of 3, 4, and 5 L h^{-1} $plant^{-1}$, at the end of growth period.

From the data it can clear that the highest percentage of root lengths were 11.41, 29.49 and 15.42% respectively at soilless systems of “Sap” at growing period of 10 days, “Shp” at growing period of 10 days and “Ss” at growing period of 20 days. These results due to the seedlings' rapid adaptation to continued growth at the beginning of the planting period due to the availability of suitable environmental conditions. Thus the maximum percentage of root lengths were 90.01, 94.29 and 81.59% respectively at soilless systems of “Sap” at water flow rate of 3 L h^{-1} $plant^{-1}$, “Shp” at growing period of 3 L h^{-1} $plant^{-1}$ and “Ss” at growing period of 5 L h^{-1} $plant^{-1}$. These results due to providing sufficient air for plant roots to breathe at an irrigation rate of 3 L h^{-1} $plant^{-1}$ compared to other rates, which led to an increase in the root mass. Whereas, at evaluate the all soilless system at the end of the growth period, the average of root length were 45.92, 39.48 and 30.71 cm respectively at “Sap”, “Shp” and “Ss” systems. These results mean that the highest root length achieved at the end of growth period in “Sap” system. Generally, aeroponic system improves the growth rate of the plants by making the oxygen available to the roots; these results are in agreement with those [30, 31, 32, 24].

From that trend of the results it can noticed that there was not any overlapping (interference) between roots of the growing plants as a result of choosing a suitable distance (50 cm) apart between plants during different growth stages. If there is any overlapping existed it was limited. These results were in agreement with [33, 16].

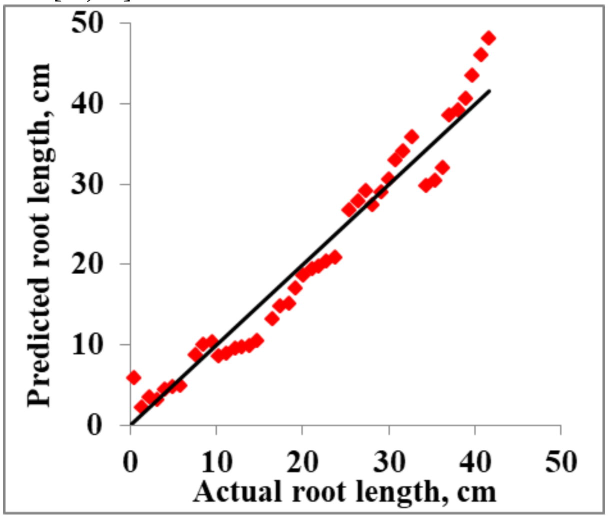


Fig. (6): The relationship between the predicted and the actual root length of basil plants

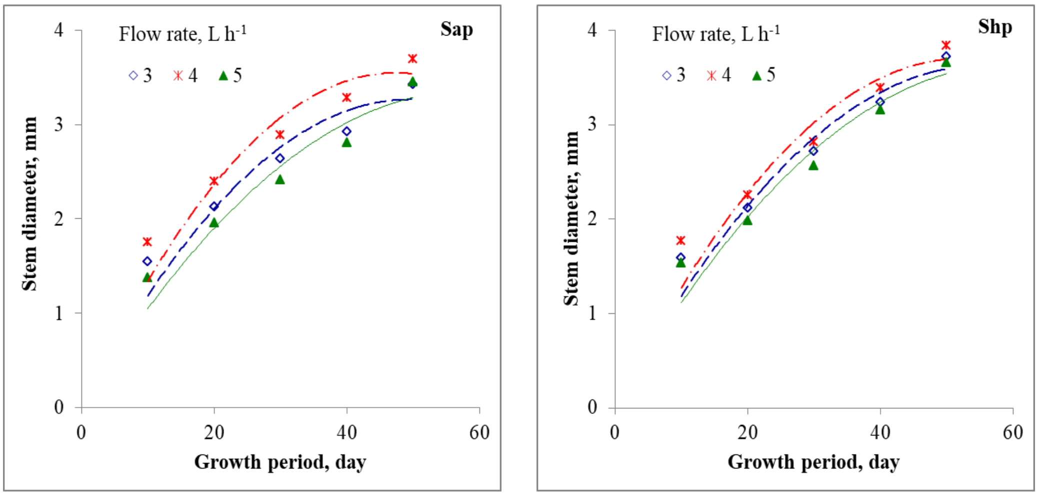
The multiple regression analysis of the soilless systems (Ss), growth periods (Gp) and water flow rates (Fr) had a highly significant linear relationship with the root length (Lr). The best fit equation to explain the correlation between the root length (Lr) and each of studied variables could be indicated as follows:

$$Lr = -50.48 - 2.661Ss + 0.893Gp + 0.933Fr \quad \text{with} \quad R^2 = 0.9455$$

Moreover, the regression analysis showed that the root length (Lr) was inversely proportional to the soilless systems (Ss) and a directly proportion to the growth period (Gp) and water flow rate (Fr). However Fig (6) shows the relationship between the predicted and the actual root length of basil plants with the coefficient of determination of r^2 = 0.9455.

3.3. Effect of the studied variables on basil stem diameter

Fig (7) shows the effect of growth periods on the basil stem diameter at different water flow rates (3, 4 and 5 L h^{-1} $plant^{-1}$) and different soilless culture systems (aeroponic, hydroponic and substrate systems). From the results it can indicate that the stem diameter of basil plant increases with increasing water growth periods for all soilless culture. It could be seen that the in soilless culture system of “Sap” the stem diameter of basil plants increased from 1.37, 1.24, 1.11 and 1.17 times respectively at the growth periods increased by 10 to 20, 20 to 30, 30 to 40 and 40 to 50 at water flow rate of 3 L.h^{-1} $plant^{-1}$. While in “Sap” system, and at the same conditions of water flow rate but at 4 and 5 L.h^{-1} $plant^{-1}$, the increase in stem diameters were 1.37, 1.20, 1.13 and 1.13; and 1.42, 1.23, 1.16 and 1.23 times respectively. Consequently, the same trends of stem diameters were found at the other soilless systems “Shp” and “Ss”. On the other side, at “Sap” system the stem diameter of basil plants increase as a percentage of about 54.81, 52.70 and 60.00% respectively at 3, 4 and 5 L L.h^{-1} $plant^{-1}$ by increase the growth period from 10 to 50 days. However, at “Shp” system the increasing percentage in basil stem diameters were 57.41, 54.05 and 58.08% respectively at 3, 4 and 5 L L.h^{-1} $plant^{-1}$ by increase the growth period from 10 to 50 days. The corresponding percentage at tested in “Ss” system were 52.65, 50.26 and 55.58% respectively at 3, 4 and 5 L L.h^{-1} $plant^{-1}$ by increase the growth period from 10 to 50 days. Whereas, at evaluate the all soilless system at the end of the growth period, the average of stem diameter were 3.53, 3.73 and 3.81 cm respectively at “Sap”, “Shp” and “Ss” systems. These results mean that the highest stem diameter achieved at the end of growth period in “Ss” system. These results may be due to the suitable balance of the all conditions of water-air and nutrients which allow a good plant growth.



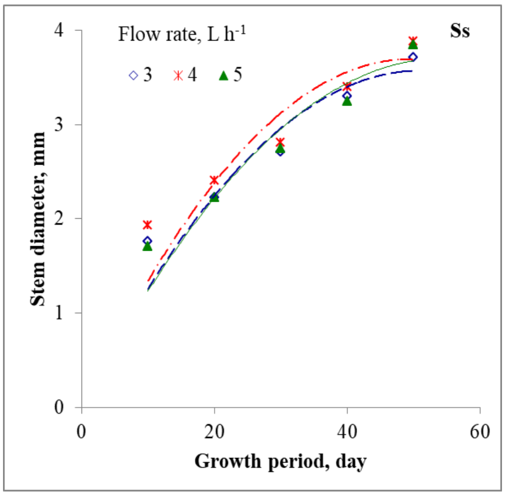


Fig. (7): The relationship between stem diameter and growth period at different irrigated-water flow rate and different soilless systems.

The multiple regression analysis of the showed that the soilless systems (Ss), growth period (Gp) and water flow rate (Fr) had a highly significant linear relationship with the stem diameter (Ds). The best fit equation to explain the correlation between the stem diameter (Ds) and each of studied variables could be indicated as follows:

$$Ds = 1.094 + 0.107Ss + 0.051Gp - 0.035Fr \quad \text{with} \quad R^2 = 0.9694$$

Moreover, the regression analysis showed that the shoot length (Lsh) was inversely proportional to the water flow rate (Fr) and a directly proportion to the soilless systems (Ss) and growth period (Gp). However Fig (8) shows the relationship between the predicted and the actual stem diameter of basil plants with the coefficient of determination of r^2 = 0.9694.

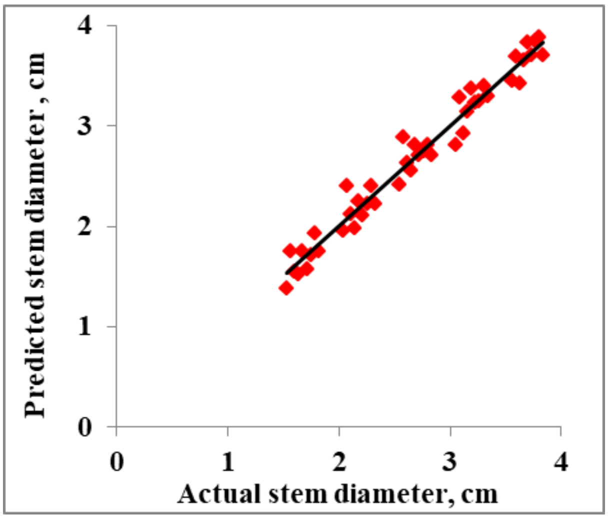


Fig. (8): The relationship between the predicted and the actual stem diameter of basil plants

3.4. Effect of the studied variables on chlorophyll in basil leaves

Table (1) shows the effect of different soilless culture systems (aeroponic, hydroponic and substrate systems) and different water flow rate (3, 4 and 5 L h^{-1} $plant^{-1}$) on the chlorophyll of basil plants during the growth period (50 days). The results indicate that, the chlorophyll of basil plants grown in aeroponic system (35.04 SPAD) was more than those of hydroponic (34.17 SPAD) and substrate (33.25 SPAD) systems during the growth period. Also, the results indicate that, the chlorophyll of basil plants recorded 34.89, 36.70 and 34.97 SPAD at the end growth period of "Sap", "Shp" and "Ss" respectively. The maximum chlorophyll of basil plants were 39.43, 38.72 and 39.03 SPAD respectively at "Sap" culture system, 3 L h^{-1} $plant^{-1}$ water flow rate and 20 days growth period; "Shp" culture system, 3 L h^{-1} $plant^{-1}$ water flow rate and 50 days growth period; and "Ss" culture system, 4 L h^{-1} $plant^{-1}$ water flow rate and 40 days growth period. However, the minimum coefficient of variance (8.47 and 5.20 %) found at the water flow rate of 4 and 5 L h^{-1} $plant^{-1}$ respectively, and at "Sap" culture system through the average growth period. These results mean that there is a balance to arrive of fertilizer from the roots to the vegetative group, enabling the vegetative group to produce a strong plant. This was achieved through the results for root length and vegetative length at the "Sap" culture system when adding 4 L h^{-1} $plant^{-1}$ water flow rate.

Table (1): The chlorophyll of basil plants grown in different soilless systems and flow rate.

Growth Period, day	Flow rate, L h^{-1}	Soilless Culture System		
		Aeroponic	Hydroponic	Substrate
		Chlorophyll of Basil Plants, SPAD		
	3	26.76	32.13	31.19
10	4	30.50	29.65	30.23
	5	32.13	28.70	29.77
	3	39.43	29.97	29.01
20	4	36.67	27.37	28.34
	5	34.67	30.13	31.25
	3	35.73	37.77	32.91
30	4	38.13	37.50	34.20
	5	36.83	36.91	34.13
	3	37.41	38.01	37.47
40	4	37.10	37.63	39.03
	5	35.53	36.70	36.33
	3	36.05	38.72	36.52
50	4	34.99	36.45	35.33
	5	33.62	34.94	33.07

3.5. Effect of the studied variables on fresh and dry mass of basil shoot

Figs (9 and 10) show the effect of different soilless culture systems (aeroponic, hydroponic and substrate systems) and different water flow rate (3, 4 and 5 L h^{-1} $plant^{-1}$) on the fresh and dry mass of shoot of basil plants at the end of growth period (50 days). The results indicate that, the shoot fresh and dry mass of basil plants grown in 4 L h^{-1} $plant^{-1}$ was more than those of different water flow rates of 3 and 5 L h^{-1} $plant^{-1}$ of about 5.54 and 7.30% and 6.29 and 10.56% respectively. Also, the shoots fresh and dry mass of basil plants grown in aeroponic system was more than those of hydroponic and substrate systems of about 34.90 and 40.72% and 33.70 and 43.42% respectively at the end of experimental period. The optimum amount of nutrient availability, sufficient oxygen in the root zone and the suitable osmotic pressure in the solution in addition to proper temperature are the main parameters affecting the enhancement of growth rate of plant in the aeroponic system [34].

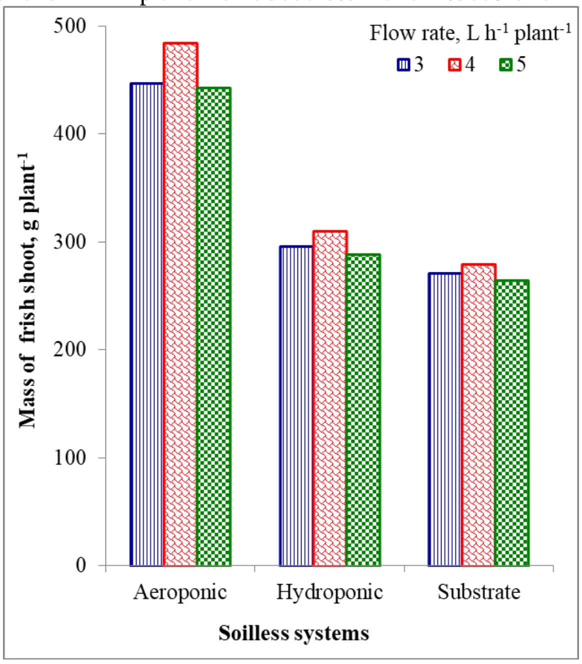


Fig. (9): Effect of different soilless culture systems and flow rate on the fresh shoot mass of basil plants.

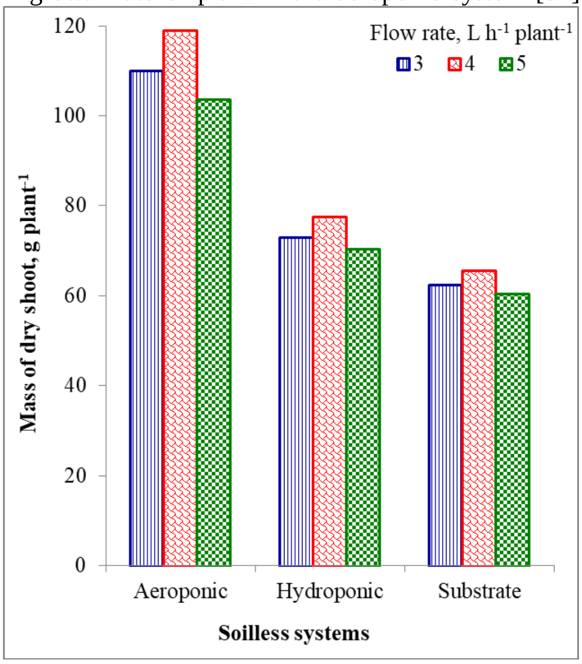


Fig. (10): Effect of different soilless culture systems and flow rate on the shoot dry mass of basil plants.

3.6. Effect of the studied variables on fresh and dry mass of root

Figs (11 and 12) show the influence of various soilless culture systems (aeroponic, hydroponic and substrate systems) and different water flow rate (3, 4 and 5 L h^{-1} $plant^{-1}$) on the fresh and dry mass of basil plants roots at the end of growth period (50 days). The results indicate that, the root fresh and dry mass of basil plants grown in 4 L h^{-1} plant^{-1} was more than those of different water flow rates of 3 and 5 L h^{-1} plant^{-1} of about 7.03 and 8.89% and 8.05 and 11.12% respectively. Also, the root fresh and dry mass of basil plants grown in aeroponic system was more than those of hydroponic and substrate systems of about 24.20 and 29.69% and 35.77 and 44.12% respectively at the end of experimental period.

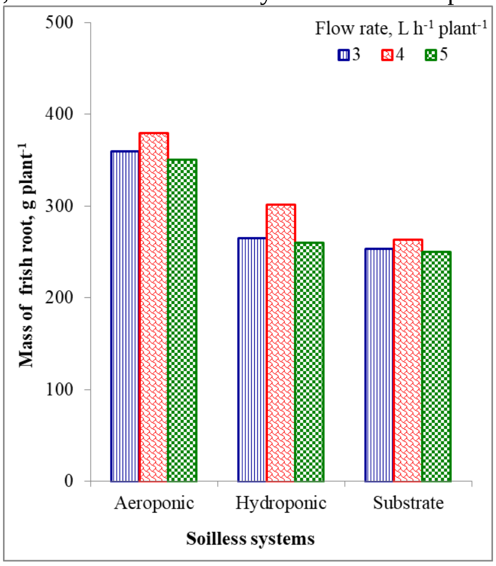


Fig. (11): Effect of different soilless culture systems and flow rate on the fresh root mass of basil plants.

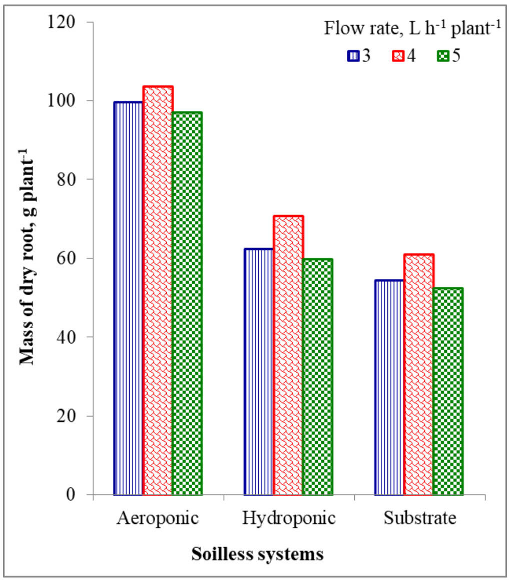


Fig. (12): Effect of different soilless culture systems and flow rate on the root dry mass of basil plants.

3.7. Effect of the studied variables on nutrients uptake by basil plants

Table (2) shows the influence of various soilless culture systems (aeroponic, hydroponic and substrate systems) and different water flow rate (3, 4 and 5 L h^{-1} plant^{-1}) on nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) uptake of basil plants at the end of growth period (50 days). The results indicate that the nutrients uptake (N, P, K, Ca and Mg) by the basil plants were higher in aeroponic system compared those of hydroponic and substrate systems. The results also indicate that, the nutrients uptake (N, P, K, Ca and Mg) by the basil plants grown in 4 L h^{-1} plant^{-1} was more than those of different water flow rates of 3 and 5 L h^{-1} plant^{-1} of about 3.51 and 6.44% ; 5.27 and 7.51%; 1.94 and 3.07%, 2.92 and 4.33% and 4.48 and 6.03% respectively. Therefore, the nutrients uptake (N, P, K, Ca and Mg) by the basil plants grown in aeroponic system was more than those of hydroponic and substrate systems of about 14.57 and 31.01%; 16.26 and 47.99%; 5.89 and 17.58%; 6.58 and 17.82% and 15.19 and 21.49% respectively at the end of experimental period, which is agreed with those obtained by [35, 24].

Table (2): The nutrients uptake of basil plants grown in different soilless systems.

Nutrient	**Flow rate, L h^{-1}**	**Soilless Culture Systems**		
		Aeroponic	**Hydroponic**	**Substrate**
		Nutrients Uptake, mg plant^{-1}		
N	3	690.77	592.31	472.12
	4	723.64	605.72	489.62
	5	659.31	573.64	468.83
P	3	243.19	201.55	123.60
	4	251.20	212.91	135.86
	5	236.59	197.64	120.71
K	3	740.27	698.44	611.21
	4	754.29	710.03	626.17
	5	735.51	690.17	600.62
Ca	3	502.03	468.79	413.43
	4	519.73	484.96	421.20
	5	492.84	461.22	410.04
Mg	3	211.37	181.15	165.90
	4	223.66	187.05	173.89
	5	207.67	176.89	164.81

4. Conclusions

The experiment was carried out to determine the favourable cultivation system and irrigation levels for cultivate basil plants at soilless technique. It is concluded that, the optimum appropriate to obtain the high quality and production of basil plants which cultivation in soilless system is the aeroponic at water flow rate of 4 L h^{-1} $plant^{-1}$ and the end of growth period. At this conditions it achieved the longest vegetative group of 67.45 cm, the root group of 48.21 cm, the stem diameter of 3.7 mm, the chlorophyll percentage in the leaves of 39.43, the fresh mass of the vegetative group of 483.25 g, the dry mass of the vegetative group of 118.93 g, the fresh mass of the root group of 379.3 g, the dry mass of the root group of 103.45 g, and the consumption rate of fertilizer elements (nitrogen 723.64 mg, phosphorus 251.2 mg, potassium 754.29 mg, calcium 519.73 mg, and magnesium 223.66 mg).

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