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Produce and Quality of Mint Crop Affected by Soilless Cultivation Systems

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Abstract

With the feast soilless systems, the most appropriate choice of plant cultivation while controlling the neighbouring environmental conditions provides the opportunity for abundant and high-quality production. Therefore, this research aims to observe the optimal environmental conditions to obtain the best quality and highest safety production of mint plants. The cultivation systems, seedlings, and means of adding irrigation and fertilization were prepared. The studied variables include growing mint seedlings in three soilless systems (substrate, hydroponics, and aeroponics) and adding water at three rates (1.0, 1.5, and 2.0 litters/hour/plant). Plant properties were observed during growth its age until the 50 days. The efficiency of the soilless system was determined by measuring productivity represented by the fresh and dry masses of both the vegetative and root parts of the plant, which recorded the highest values of approximately 4.189, 0.779, 3.068 and 0.509 kg/m2, as well as the nutrients concentrated in the plants, which recorded 457.22, 203.62, 307.89, 463.60, 213.76 mg for each of N, Mg, Ca, K and P respectively, in the aeroponic system at rate of add water of 1.5 litters/hour/plant. The best specifications for mint plants were determined as 0.29mm, 49.02cm and 32.48 cm for each of the stem diameter, length of the green part, and length of the root, respectively, which were recorded at the same levels as the previously mentioned variables.

Keywords: Aromatic, Environment control, Condition, Nutrient needed, Physical properties

1. Introduction

Mint (*Mentha piperita*) is cultivated globally in diverse agro-climatic environments [1]. In Egypt, mint is considered an economically significant crop because of its medicinal and aromatic properties. By improving its quality and increasing the production it can get to a strategic crop. -In 2020, mint production reached 164,000 tons, with 1,530 tons exported, valued at approximately 58,693 EGP [2]**.**

Mint is commonly used in various herbal beverages, with the leaves being the most utilized part. These leaves possess numerous health benefits, including antiseptic, digestive, and antioxidant properties, as well as relief from ear discomfort and anti-asthmatic effects. Additionally, the essential oils extracted from mint are employed in pharmaceuticals to support respiratory health, act as antispasmodics, and help prevent issues such as flatulence, bile duct inflammation, gastritis, gallbladder spasms, and gastrointestinal colic. The plant extracts can also significantly reduce blood sugar levels, certain unstable sulfur compounds, and arsenic-related toxicity [3, 4, 5]. The shift from traditional soil-based cultivation to soilless methods was primarily driven by the need to make farming more accessible for urban populations, offering an affordable, sustainable, and efficient solution to meet the increasing demand for agricultural products [6].

Soilless systems are important in areas with climate changes that are dangerous to plant growth, as all environmental conditions can be precisely controlled and adjusted to provide the appropriate environmental and climatic conditions for growth [7, 8] The data analysing hydroponic cultivation systems and they explain the most important factors affecting productivity. They also evaluated their sustainability and clarify the environmental factors affected by them. Furthermore, they present techniques to develop the hydroponic cultivation systems.

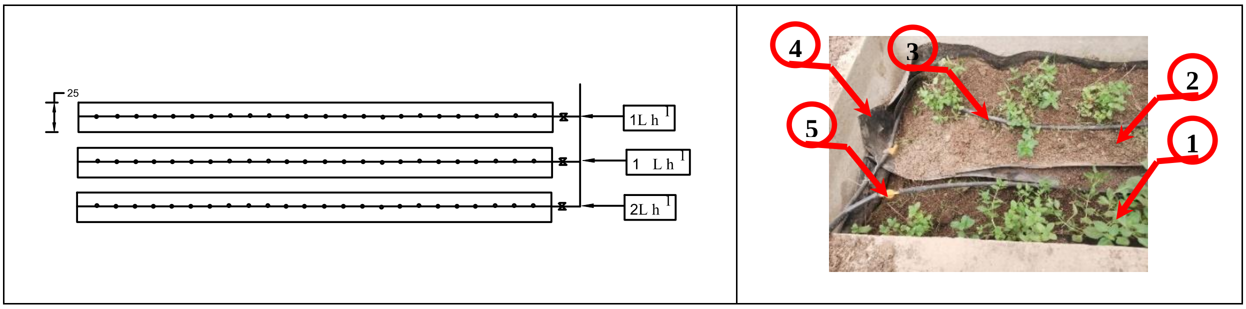
A significant impetus for adopting soilless cultivation is the decreased reliance on fertilizers, growth regulators, pesticides, herbicides, and other detrimental chemicals. This approach not only supports national economies but also guarantees unadulterated food [9]. Hydroponics and aeroponics, which involve growing plants without soil, present a considerable opportunity for commercial success in crop production, especially for fast-growing leafy vegetables. These systems are designed as modular units and can be constructed using relatively inexpensive materials and minimal technical knowledge [10]. While soil is the most common growing medium, providing essential nutrients, water, air, and anchorage for plant growth, it can also present limitations such as unfavorable composition, poor drainage, unsuitable pH levels, and the presence of disease-causing organisms and nematodes [11]. Aeroponics is a promising soilless farming technique that can help address future food shortages [12]. Plants grown in aquaponics systems have shown increased dry weight, likely due to a greater presence of beneficial microorganisms that improve nutrient absorption, minimize plant diseases, especially which borne from soil, compared to other systems[13, 14, 15, 16] found that mint can cultivated in diverse hydroponic components: grow pipes, raft and ebb and flood gravel substrate system. The plant heights were 57.7 ± 13.1; 58.0 ± 17.7 and 63.6 ± 9.9 cm, respectively at gravel, raft and grow pipe. While the root lengths were 64.3 ± 20.5; 59.4 ± 15.2 and 29.7 ± 7.8 cm at two and four fold and grow pipes gravel substrate, respectively. Also, the mass of fresh root for two-fold and four-fold, grow pipes and gravel substrate were 42.8 ± 29.9, 41.3 ± 25.7 and 9.4 ± 9.4 g, respectively. Also, the highest fresh biomass was found in raft, followed by the grow pipes and lowest at the gravel substrate were 1.276 ± 0.0334, 1.042 ± 0.0358 and 0.686 ± 0.0982 g, respectively. Finally, they cleared the leaves quality of spearmint was reasonable, may due the reduced chlorophyll content (SPAD). Generally, they concluded that the optimal aquaponic culture in pipes.

Consequently, this study seeks to identify the optimal environmental conditions for achieving the health best quality and highest productivity of mint plants.

2. Materials and Methods

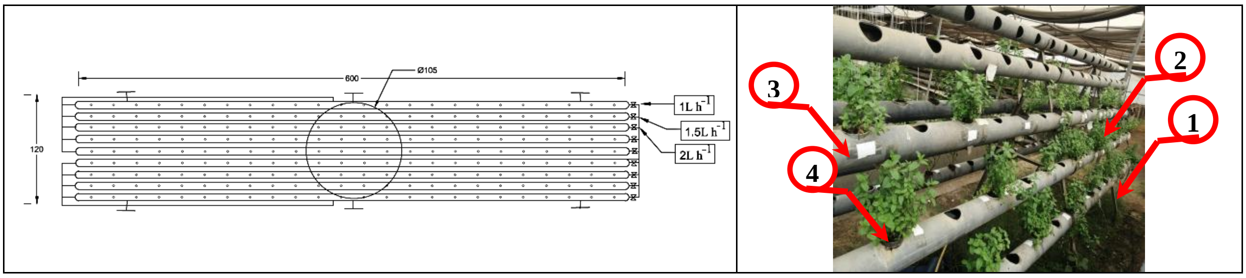
To achieve the aim of the work, the construction of some soilless system were built at 2024 through success cultivate season from June to August months. The experiments done in Faculty of Agriculture Moshtohor, Benha University, Egypt, at Fish Farms and Protected Houses Center. The experiments tests were evaluated the effect of studied variables on the efficiency of the soilless system and the specifications of mint plants. The materials required are the mint seedling, nutrient solution and soilless media. The seedling mints with 14 day ages were chosen the health and right plants. Then main nutrient adds on the water to complete 1000L. The electrical conductivity (EC), pH, as well as the air and water temperatures, relative humidity, and light intensity were all adjusted to realize the requirements of the seedlings and each growth stage of the mint plant. The soilless media consists of a mixture of standard peat moss, perlite, and vermiculite in a ratio of 2:1:1. Finally, the designs of the selected soilless systems are illustrated in Figures (1) through (3) as follows:

The all system mainly contains the media as above illustrated which put in planting cups with (7 × 7 cm diameter and height respectively) “hydro and aero ponics” and in pool “substrate”. Also, the add water supply from the main tank to irrigated tubes by drip, sprinklers and absorb from the bottom of the pipes respectively for substrates, hydroponic and aeroponic soilless systems. The specifications of the each system are; (1) substrates system (Figure 2) is made from polyethylene sheet with 1.0 mm thickness. The system includes three rows with 4.0 × 0.25 × 0.20 m for length, width and depth respectively. The number of plants per square meter is 25 plants. (2) hydroponic system (Figure 3) has “A” shape. It frame made of iron. The three stands were constructed with the dimensions of 1.2 × 1.7 m for width and height respectively. Each stand can contain nine (PVC) pipes. The pipes has diameter of 110 mm and 6.0 m long. The stands were prepared to give the slope of 2.0 % along each pipe. To deliver the nutrient solution from the tank to the pipe, the tubes with 16 mm diameter were used in closed system. The number of plants per square meter is 26 plants. (3) aeroponic system (Figure 4) is made of three pools with the rectangular shape. Each of it has dimensions of 80 × 40 × 50 cm length, width and height respectively. The pool placed on tables with 1.0 m high from the ground. The pools in this system were covered by box with the upper plane of foam sheet. The foam sheet was drilling by holes to fix the cup contains of plant seedlings. The number of plants per square meter is 25 plants. The circular polyethylene tank of the nutrient solution system 1000 litter capacity was used for collecting the drainage solution by gravity from the ends of the soilless systems. The power source is the pump with 367.75 W (0.5 hp) Model First QB60 – Flow Rate 30 L min^{-1} – Head 25 m, made in China used to supply the adding the mixture of nutrients solution with water to the plants.



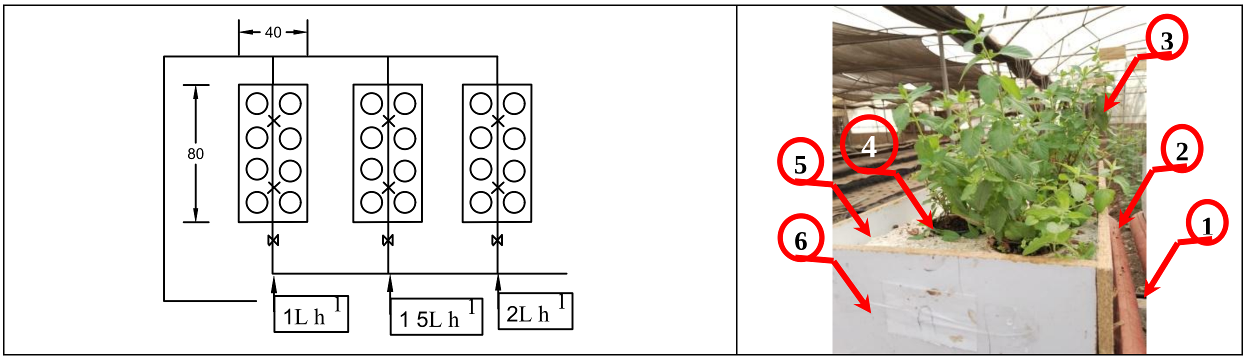
1. Mint plants, 2. Media, 3. Water flow tube (16 mm), 4. Polyethylene sheet, 5. Water valve,

Fig. 1: The component of substrate system



1. Stand frame, 2. Mint plants, 3. PVC pipe, 4. Cup

Fig. 2: The component of hydroponic system



1. Table, 2. Pool, 3. Mint plant, 4. Cup, 5. Foam sheet, 6. Support box

Fig. 3: The component of aeroponic system

Experimental procedure:

Pre-experiments:

Prepare the nutrient solution: the amounts of nutrient are appropriate of mint plants are $Ca(NO_3)_2$, 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, B=0.5, Co=0.03, Cu=0.02, Fe=14, Mn=0.5, Mo=0.01 and Zn=0.05). The nutrient solution pH and (EC) were further adjusted to 6.5-7.0 and 1.4-1.8 dS m^{-1}, respectively.

The environ condition was periodical tested and automatic adjust at average air ambient temperature was 25.97±4.37 °C and the average water temperature was 24.03±3.92 °C. The relative humidity was about 65.4% and the light intensity was 338.55±40.06 W m^{-2}.

The tests to evaluate the soilless culture systems under study contain the variables of:

1- Soilless culture systems three levels of; substrate, hydroponic and aeroponic "Scs, Sch, and Sca".
2- Rate of add water "Aw" three levels of are 1.0, 1.5 and 2.0 L h^{-1} $plant^{-1}$.

The measurement and the evaluation of the system quality (productivity as mass of plant component "kg.m^{2}" and nutrients needed "mg"), and the plant properties (chlorophyll "SPAD", stem diameters "mm" and shoot and root lengths "cm"). The all measurements were measured periodically at the end of ten days through the 50 days "plant age (Pa)". While the elements of system quality were determine at the end of 50^{th} day "end of plant age (Pa)".

The measuring instruments and methods are:

1- The digital balance with the accuracy of ±0.01 g used to determine the fresh and dry mass of shoot and root.
2- Dryer oven used to dry the plants at 65±1.0 ºC until constant mass.
3- The standard chemical analysis methods which described by [17, 18, 19, 20] to determine the macro elements (N, P). Photofatometer with range of 0 - 160 mmol L^{-1}, model Jenway PFP7 made in USA used to measure K, Ca, Mg and P contents in the nutrients needed every weeks to balance component in drainage solution which can recycling uses.
4- Chlorophyll meter with the accuracy of ±1.0 SPAD unit model Minolta SPAD-502 - made in Japan used to measure the higher leaves of the tallest branch.
5- Digital vernier caliper with the accuracy of ±0.01mm used to measure the diameter of branch in their middle.
6- Tab meter with the accuracy of ±1.0 mm used to measure the tallest branch length and the main length root.

3. Results and Discussion

3.1. Effect of soilless systems and rate of add water on system quality

- **Mass of production**

Fig (4) shows the effect of rate of add water on productivity mass for mint components (fresh and dry shoot and fresh and dry root) at different cultivated soilless systems under study (substrate, hydroponic and aeroponic) which recorded at the end plant age (50 days). The results designate that, the fresh and dry mass of shoots grown in 1.5 L h^{-1} $plant^{-1}$ rate of add water is the highest compared with the other rate of add water under tested of 1.0 and 2.0 L h^{-1} $plant^{-1}$. They recorded increment percentage for fresh and dry mass of about 4.94 and 8.87% and 5.49 and 9.80% respectively. Similarly, the fresh and dry mass of mint plants shoots grown in aeroponic system was higher than the other systems of hydroponic and substrate as increment percentage of about 39.49 and 40.43% and 15.93 and 24.35% respectively at the end plant age.

Moreover, the ANOVA test for fresh shoot cleared that the interaction of the factors under study had a significant effect of F value. Also, P-value showed that the most significant factor is “Sc followed by the “Aw” that has non-significant effect. Which the regression coefficient recorded “R^2 = 0.6529”. While, the ANOVA test for dry shoot shows that the interaction of the factors under study had a high significant effect of F value. Also, P-value showed that the most significant factor is “Sc followed by the “Aw” that has non-significant effect. However the regression coefficient recorded “R^2 = 0.8736”.

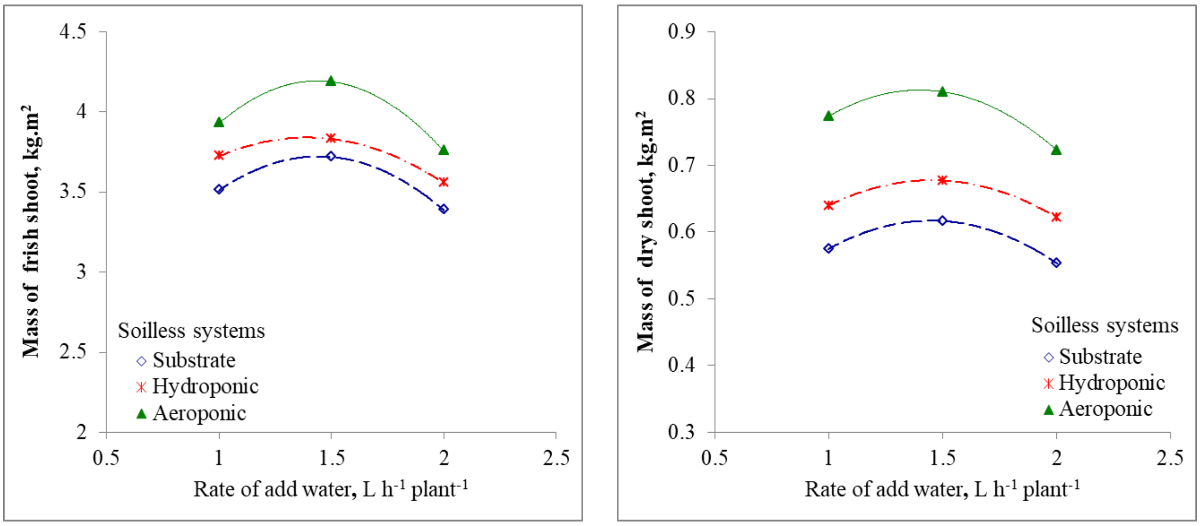


Fig. 4: Effect of rate of add water on productivity as masses of shoots.

Moreover from Figure (5) the results indicate that, the root fresh and dry mass of mint plants grown in 1.5 L h^{-1} $plant^{-1}$ has the highest masses of those other rate of add water of 1.0 and 2.0 L h^{-1} $plant^{-1}$. They increment percentage noted fresh and dry mass of about 5.60 and 7.80% and 4.58 and 7.61% respectively. Also, the root fresh and dry mass of mint plants shoots grown in aeroponic system was more than those of hydroponic and substrate systems as increment percentage of about 11.12 and 18.14% and 12.06 and 21.92% respectively at the at the end plant age. These results may due to use the both of moderate rate of add water (1.5 L h^{-1} $plant^{-1}$) and aeroponic system allow the sufficient oxygen to breathe from in the root, appropriate amount of nutrient can uptake, and the proper osmotic pressure in the solution. These are main factors can the improvement of plant growth. The above results were agreement with [21].

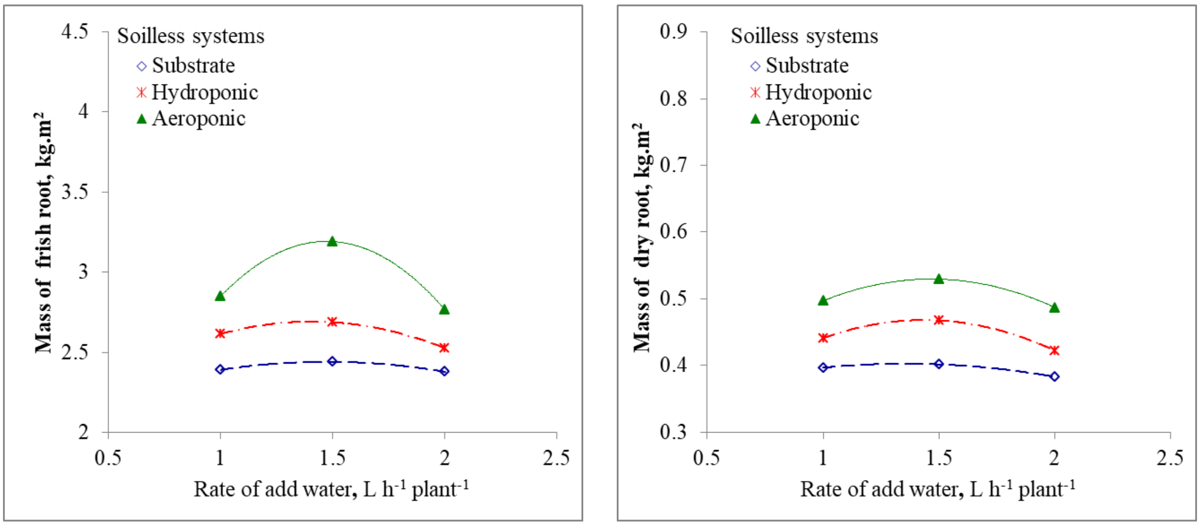


Fig. 5: Effect of rate of add water on productivity as masses of roots.

Additionally, the ANOVA test for fresh root found that the interaction of the factors under study had a significant effect of F value. Also, P-value showed that the most significant factor is "Sc followed by the "Aw" that has non-significant effect. However the regression coefficient recorded "R^2 = 0.7845". Besides, the ANOVA test for dry root cleared that the interaction of the factors under study had a highly significant effect of F value. Also, P-value showed that the most significant factor is "Sc followed by the "Aw" that has non-significant effect. However the regression coefficient recorded "R^2 = 0.9045".

- **Nutrients needed**

Figure (6) shows the effect of soilless systems at different elements of nutrient on nutrient concentration for mint plants [nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg)] at the end of plant age (50 days). The results indicate that the nutrients concentration (N, P, K, Ca and Mg) by the mint plants grown in 1.5 L h^{-1} $plant^{-1}$ was more than those of different rates of add water of 1.0 and 2.0 L h^{-1} $plant^{-1}$ about 3.26 and 5.14%; 3.00 and 5.71%; 4.03 and 5.3%, 4.34 and 7.53%; and 3.97 and 6.88% respectively. Where, the nutrients concentrate (N, P, K, Ca and Mg) by the mint plants grown in aeroponic system was more than those of hydroponic and substrate systems of about 6.98 and 20.34%; 10.34 and 14.37%; 4.41 and 8.72%; 2.45 and 5.42%; and 5.66 and 10.16% respectively at the end of experimental period, which is agreed with those obtained by [22, 15, 16, 23, 24].

Additionally, the ANOVA test for nutrient concentration for mint plants showed that the interaction of the factors under study had a highly significant effect of F value. Also, P-value showed that the most significant factor is "Sc" followed by the "Aw" that has non-significant effect. However the regression coefficient recorded "R^2 = 0.9224, 0.8537, 0.7263 and 0.7432" respectively at (N, P, K and Mg). But Ca has a non-significant effect for the both factors of "Sc and Aw".

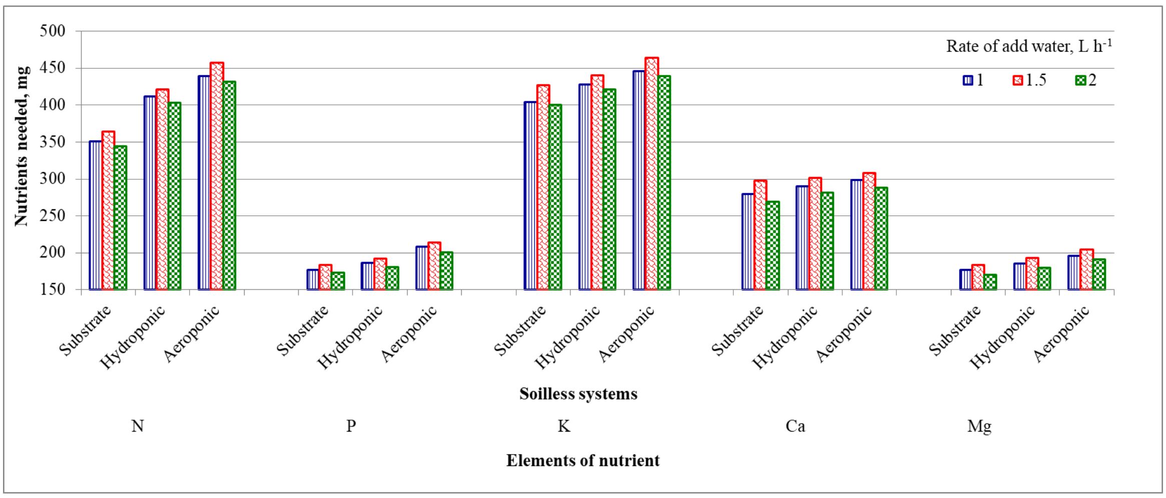


Fig. 6: Effect of soilless systems at different elements of nutrient on nutrient needed.

Effect of soilless systems and rate of add water on plant properties

- **Chlorophyll contents in leaves**

Figure (7) shows the effect of plant age on chlorophyll contents in mint leaves at different soilless systems under study (substrate, hydroponic and aeroponic) during the plant ages every 10 days. The results indicate that, the average chlorophyll contents of mint leaves grown in substrate, hydroponic and aeroponic systems were 29.83, 29.82 and 27.65 SPAD respectively during the plant age. Also, the results indicate that, the chlorophyll contents of mint leaves recorded 30.94, 31.55 and 31.90 SPAD at the end plant age of “Sca”, “Sch” and “Scs” respectively. The maximum chlorophyll contents of mint leaves were 32.48, 33.70 and 34.56 SPAD respectively at “Sca”, “Sch” and “Scs” culture system at 1.0 L h^{-1} $plant^{-1}$ rate of add water and 40 days plant age. 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 “Sca” culture system when adding 1.5 L h^{-1} $plant^{-1}$ rate of add water. These results are agreement with [15, 16]**.**

Likewise, the ANOVA test for chlorophyll content cleared that the interaction of the factors under study had a highly significant effect of F value. Also, P-value showed that the most significant factor is “Pa” followed by the “Sc” then the factor of “AW that has non-significant effect. However the regression coefficient recorded “R^2 = 0.6373”.

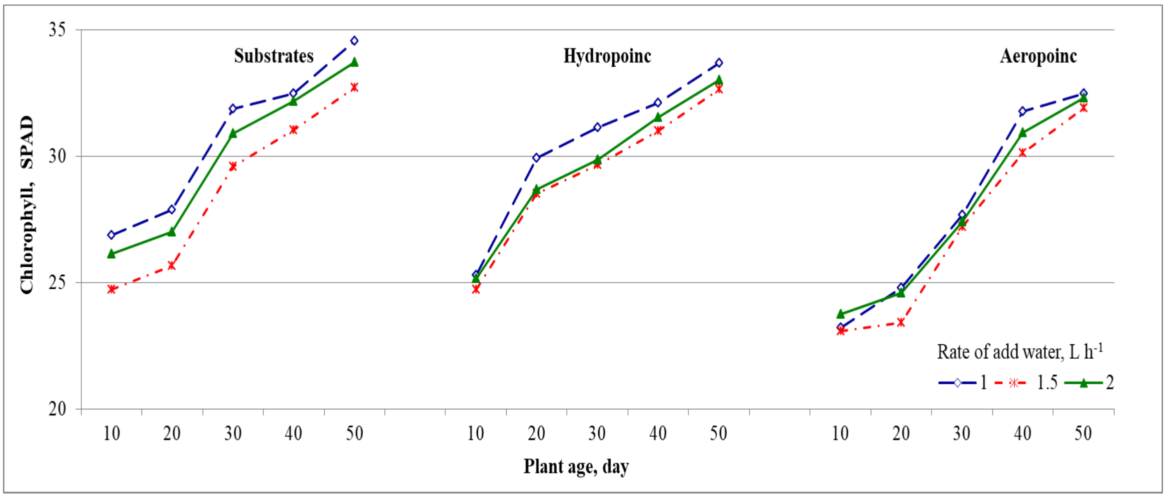


Fig. 7: Effect of plant age on chlorophyll.

- **Stem diameters**

Figure (8) shows the effects of plant age on mint stem diameter at different soilless systems under study (substrate, hydroponic and aeroponic) during the plant ages every 10 days. From the results it can indicate that the stem diameter of mint plant increases with increasing plant ages for all soilless culture. It could be seen that the in soilless culture system of “Sca” the stem diameter of mint plants increased about 1.21, 1.23, 1.21 and 1.09 times respectively at the plant ages increased by 10 to 20, 20 to 30, 30 to 40 and 40 to 50 at rate of add water of 1.0 $L.h^{-1}$ $plant^{-1}$. While in “Sca” system, and at the same conditions of rate of add water but at 1.5 and 2.0 $L.h^{-1}$ $plant^{-1}$, the increase in stem diameters were 1.24, 1.21, 1.18 and 1.16; and 1.24, 1.20, 1.19 and 1.20 times respectively. Subsequently, the same trends of stem diameters were found at the other soilless systems “Sch” and “Scs”. On the other side, at “Sca” system the stem diameter of mint plants increase as a percentage of about 49.21, 51.54 and 53.33% respectively at 1.0, 1.5 and 2.0 $L.h^{-1}$ $plant^{-1}$ by increase the plant age from 10 to 50 days. However, at “Sch” system the increasing percentage in mint stem diameters were 51.58, 49.83 and 50.00% respectively at 1.0, 1.5 and 2.0 $L.h^{-1}$ $plant^{-1}$ by increase the plant age from 10 to 50 days. The corresponding percentage at tested in “Scs” system were 51.53, 49.33 and 52.90% respectively at 1.0, 1.5 and 2.0 $L.h^{-1}$ $plant^{-1}$ by increase the plant age from 10 to 50 days. Whereas, at evaluate the all soilless system at the end of the plant age, the average of stem diameter were 2.77, 2.87 and 2.95 mm respectively at “Sca”, “Sch” and “Scs” systems. These results mean that the highest stem diameter achieved at the end of plant age in “Scs” system. These results are agreement with [15, 16]**.**

Also, the ANOVA test for mint stem diameters showed that the interaction of the factors under study had a highly significant effect of F value. Also, P-value showed that the most significant factor is “Pa” followed by the “Sc” then the factor of “AW that has non-significant effect. However the regression coefficient recorded “R^2 = 0.9863”.

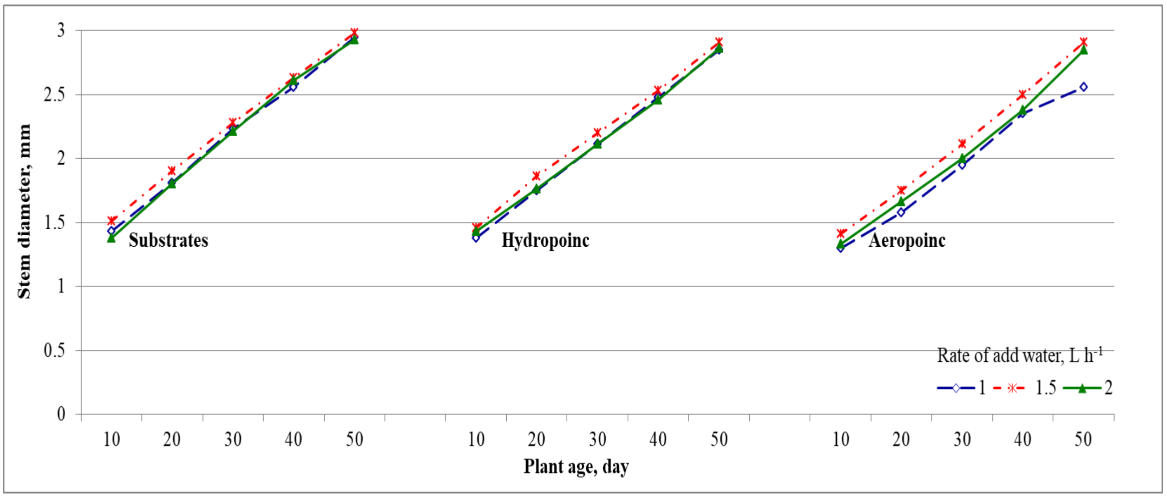


Fig. 8: Effect of plant age on stem diameter.

- **Shoot and root lengths**

As illustrated in Figure (9) the effects of plant age on mint shoot length at different soilless systems under study (substrate, hydroponic and aeroponic) during the plant ages every 10 days. From the figure it can revealed that the shoot length has a directly relationship with the increase of plant age. From the figure it can clear that, different rate of add water and different soilless systems showed that regarding to the increase of plant age from 10 to 50 days the shoot length increase from 12.96 to 43.58, 13.45 to 49.02 and 12.70 to 42.77 cm, respectively at rate of add water of 1.0, 1.5, and 2.0 L h^{-1} $plant^{-1}$ at cultivation in "Sca" system. While, at "Sch" system and the corresponding above plant age the shoot length increased from 12.51 to 39.03, 12.99 to 48.61 and 12.43 to 38.71cm, respectively at rate of add water of 1.0, 1.5 and 2.0L h^{-1} $plant^{-1}$. However at substrate system and the increasing in plant age from 10 to 50 days, the shoot length of plants were increased from 12.07 to 37.27, 12.38 to 42.87 and 11.98 to 37.65 cm respectively at 1.0, 1.5 and 2.0L h^{-1} $plant^{-1}$ of rate of add water. These previous results were agreement with the results found by [15, 16, 23]**.**

The results also indicate that, the shoot of the mint plants grown in aeroponic system were higher than those of hydroponic system and substrate system during the experimental plant age. It could be seen that the highest value of shoot length of mint plants was 49.02 cm for aeroponic system at rate of add water of 1.5 L h^{-1} $plant^{-1}$ in the end of plant age. While, the lowest value of shoot length of mint plants was about 37.27 cm, found at substrate system and plant age of 50 days. These results which is agree with those obtained by [25, 26]**.**

From the data it can clear that the highest percentage of shoot lengths were 3.64, 3.69 and 2.5% respectively at soilless systems of "Sca", "Sch" and "Scs" at plant age of 10 days. Whereas, at evaluate the all soilless system at the end of the plant age, the average of shoot length were 45.21, 42.11 and 39.26 cm respectively at "Sca", "Sch" and "Scs" systems. These results mean that the highest shoot length achieved at the end of plant age in "Sca" 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 70.26, 67.94 and 67.61% respectively at soilless systems of "Sca", "Sch" and "Scs" at rate of add water of 3 L h^{-1} $plant^{-1}$. These results due to providing sufficient air for plant roots to breathe at an irrigation rate of 1.0 L h^{-1} $plant^{-1}$ compared to other rates, which led to an increase in the vegetative mass. These results are agreement with [15, 16]**.**

Likewise, the ANOVA test for mint shoot lengths showed that the interaction of the factors under study had a highly significant effect of F value. Also, P-value showed that the most significant factor is "Pa" followed by the "Sc" then the factor of "AW that has non-significant effect. However the regression coefficient recorded "R^2 = 0.9625".

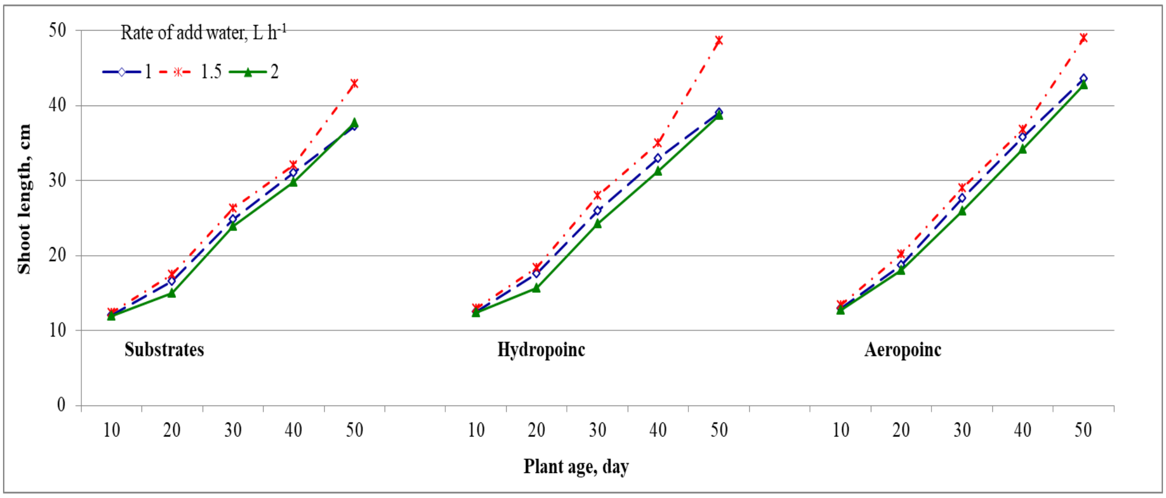


Fig. 9: Effect of plant age on shoot length.

Figure (10) shows the effects of plant age on mint root length at different soilless systems under study (substrate, hydroponic and aeroponic) during the plant ages every 10 days. From the figure it can clear that, different rate of add water and different soilless systems showed that regarding to increase of plant age from 10 to 50 days the root length increase from 2.81 to 29.91, 2.86 to 30.76 and 2.99 to 32.06 cm respectively at 1.0, 1.5 and 2.0 L.h^{-1} plant^{-1} of rate of add water at cultivation in "Sca" system. Furthermore, in "Sch" system when the plant age increased from 10 to 50 days, the root length increased from 2.79 to 28.74, 2.63 to 28.77 and 2.80 to 30.53cm respectively at 1.0, 1.5 and 2.0L h^{-1} plant^{-1} of rate of add water. Moreover in "Scs" system and at the same plant ages, the root length of mint increased from 3.64 to 26.81, 3.40 to 26.99 and 3.05 to 28.00 cm respectively at rate of add water of 1.0, 1.5 and 2.0 L.h^{-1} plant^{-1}. The results of measurements of root of the mint 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 mint plants was 32.06 cm for aeroponic system at 2.0 L h^{-1} plant^{-1} flow rate at the end of plant age, while, the lowest value of root length of mint plants was 26.81 cm was found with substrate system at the end of plant age. The root length for mint plants grown in aeroponic system were 1.47, 1.52 and 1.50 times taller than those grown in substrate system respectively at rate of add water of 1.0, 1.5, and 2.0 L h^{-1} plant^{-1}, at the end of plant age.

From the data it can clear that the highest percentage of root lengths were 13.52, 11.04 and 15.42% respectively at soilless systems of "Sca" at growing period of 20 days, "Sch" at growing period of 30 days and "Scs" 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 90.70, 90.85 and 89.1% respectively at soilless systems of "Sca" at rate of add water of 1.5 L h^{-1} plant^{-1}, "Sch" at growing period of 1.5 L h^{-1} plant^{-1} and "Scs" at growing period of 2.0 L h^{-1} plant^{-1}. These results due to providing sufficient air for plant roots to breathe at an irrigation rate of 1.5 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 plant age, the average of root length were 30.91, 29.34 and 27.26 cm respectively at "Sca", "Sch" and "Scs" systems. These results mean that the highest root length achieved at the end of plant age in "Sca" 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 [27, 28, 29, 30, 31, 23].

Moreover, the ANOVA test for mint root lengths showed that the interaction of the factors under study had a highly significant effect of F value. Also, P-value revealed that the most significant factor is "Pa" followed by the "Sc" then the factor of "AW that has non-significant effect. However the regression coefficient recorded "R^2 = 0.9703".

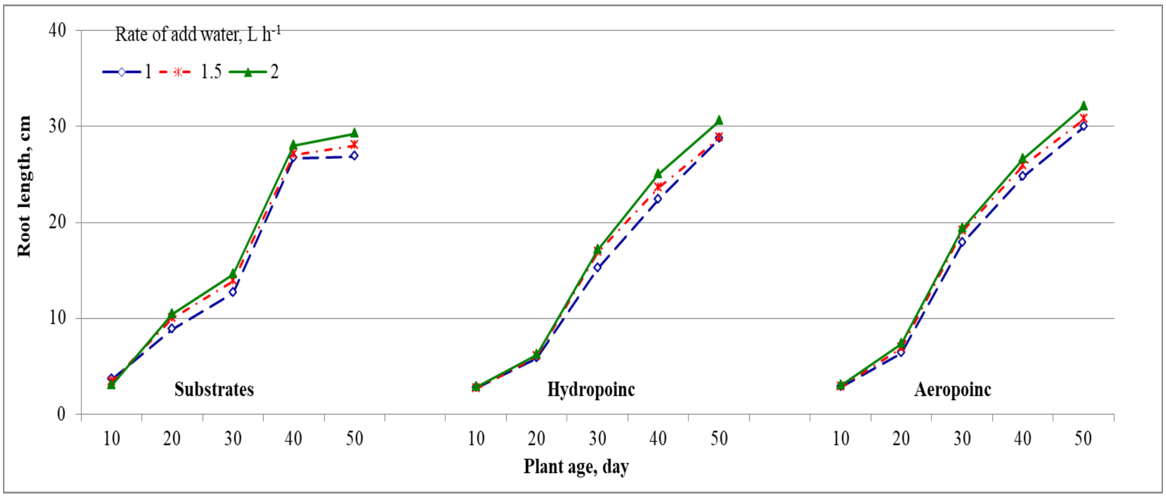


Fig. 10: Effect of plant age on root length.

4. Conclusions

The experiment was carried out to observation the optimal environmental conditions toward obtain the best quality and highest safty production of mint plants. It is concluded that, the efficiency of the soilless system was determined by measuring productivity represented by the fresh and dry mass of both the vegetative and root parts of the plant, which recorded the highest values of approximately 4.189, 0.779, 3.068 and 0.509 kg/m^2, as well as the rate of consumption of nutrients from the nutrient solution, which recorded 457.22, 203.62, 307.89, 463.60, 213.76 mg for each of N, Mg, Ca, K and P respectively, in the aeroponic system at adding water rate of 1.5 L h^{-1} plant^{-1}. The best specifications for mint plants were determined as 0.29 mm, 49.02 cm and 32.48 cm for each of the stem diameter, length of the green part, and length of root, respectively, which were recorded at the same levels as the previous studied variables.

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