EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 12
Issue: 1
Year: 2025

OPTIMIZATION OF DIFFERENT PARAMETERS FOR CULTIVATION OF *SPINACIA OLERACEA* IN NFT HYDROPONICS

Boddupalli Krishna Jaswanth[1], Pichili Vijaya Bhaskar Reddy[2] and Kiranmai Chadipiralla[1]*

[1]Vikrama Simhapuri University, Department of Biotechnology, Nellore, Andhra Pradesh-524324, A.P, India.
[2]Assam University, Diphu Campus, Department of Life Science & Bioinformatics, Diphu-782462, Assam, India.

***Corresponding Author: Kiranmai Chadipiralla**
Vikrama Simhapuri University, Department of Biotechnology, Nellore, Andhra Pradesh-524324, A.P, India.

Article Received on 09/11/2024 **Article Revised on 30/11/2024** **Article Accepted on 20/12/2024**

ABSTRACT
Hydroponic agriculture is gaining popularity all over the globe due to effective resource management and the production of high-quality food. As a result of urbanisation, natural disasters, climate change, and the indiscriminate use of herbicides and pesticides, soil-based agriculture is now confronted with several obstacles that diminish soil fertility. *Spinacia oleracea*, is an edible leafy vegetable widely cultivated in Asian countries. It is well known for its taste and medicinal properties. Spinach is rich in iron, calcium and other essential minerals. The present study focused on growing *Spinacia oleracea* in hydroponics through Nutrient Film Technique (NFT) and evaluating the effect of climatic parameters like temperature and humidity and physical parameters like, total dissolved solids (TDS), electrical conductivity (EC) and pH on the plant growth, analysed by measuring plant, shoot length, root length, number of leaves to assess plant's health. Plant is in good health condition with gradual increase in root and shoot lengths and reached highest on DAT 21 with optimal shoot length, 12.35 ± 1.0 cm and root length, 1.77 ± 0.1 cm. The optimal ranges of nutrient solution physical parameters for *Spinacia oleracea* growth in NFT were recorded as EC (1490-2660 µS/cm), pH (3.6-5.1), TDS (750- 1120 ppm) and temperature (28.1°C - 30.1°C).

KEYWORDS: Hydroponics, NFT, *Spinacia oleracea*, plant growth.

INTRODUCTION
Spinach (*Spinacia oleracea* L.) is a popular leafy green vegetable known for its high nutritional value, containing significant amounts of vitamins, minerals, and antioxidants.[1] The rise in people's health-conscious led to the production of sustainable food, which gave rise to other standby cultivation practices such as hydroponics. Hydroponics is a soilless technique of growing plants using water supplied with nutrients.[2] Nutrient Film Technique (NFT) is recommended as the most effective among other hydroponic techniques because it can limit water usage and produce higher yields.[3] This research article focuses on exploring the advantages of growing spinach using NFT hydroponics.

In contrast with the name, hydroponic systems have been reported to use less water and land than traditional soil-based agriculture, making them suitable for modern farming and water-scarce regions.[4] NFT, a specific hydroponic system, involves the continuous flow of a thin film of nutrient solution over the plant roots, allowing optimal nutrient and oxygen availability.[3] This method has been successfully employed to grow various crops, including lettuce, tomatoes, and strawberries.[2, 5]

Recently the research findings of, Agarwal et al.[6] and Syed et al.[7] has reported spinach grown in hydroponics is better than soil-grown spinach and is one of the crops that can be cultivated using hydroponics and it has a far more robust root system than soil-grown spinach. Moreover, hydroponic systems like NFT can contribute to sustainable agriculture by reducing pesticide use, minimizing the risk of soil-borne diseases, and allowing for year-round cultivation.[3,8] The nutrients can be adjusted accordingly to the plant's requirements in the controlled NFT systems, which help conserve water and reduce nutrient runoff and pollution as the nutrient solution recirculated in a loop manner.[4]

This research article will study the various aspects of spinach cultivation, including the optimal growing conditions such as, climatic parameters, essential nutrient solution specifications and requirements to provide a comprehensive understanding required for growing spinach through hydroponics using NFT.

MATERIALS AND METHODS

Location

Three weeks were spent conducting the experiment in the Department of Biotechnology at Vikrama Simhapuri University in Nellore, Andhra Pradesh. The experimental plots were maintained in a 10' x 5' x 12' shade-net house covered with a green shade net that provided 50% shade (length x wide x height).

Plant material

Spinacia oleracea seeds were placed in an inert foam material placed in the water and covered with thin sheets before being placed in the dark, as light promotes the growth of undesirable algae. It was examined frequently for the development of seedlings.

Treatments and substrates

The nutrient film technique (NFT) hydroponics system was used in order to conduct the test. Clay balls and a substance similar to inert foam were employed as the substrates (Purchased via Amazon.co.in). The macro and micronutrients were purchased from Greenloop and were a part of our everyday diet (LEAFY 200). They were made in advance in the form of stock solutions (A & B). Both Stock A and Stock B were made by independently adding different quantities of nutrient mix to the same volume of RO water. Stock A was made by adding 160 gm of nutrient mix to 1 litre of RO water, while Stock B was made by adding 170 gm of nutrient mix to 1 litre of RO water. The composition of the macronutrients comprises Ca at 23%, N at 23%, P at 7%, K at 32%, Mg at 5.3%, and S at 9%, while the composition of the micronutrients includes B, Cl, Mn, Zn, Cu, Na, Mo, Fe, and C at 0.7% each. For the first occasion, the NS that was delivered was at a half-strength, which was achieved by adding 10 millilitres of stock A and stock B to 40 litres of distilled water (TDS-50 ppm).

NFT hydroponic system

The NFT system was composed of an underground 20-L tank (PVC), a 45(W) Sub-immersible pump (18.8 x 15.5 x 12.2 cm; 778 Grams, amici Tools- India), 12.5-mm water supply pipe (RO), two 7ft -110mm 4 kg f/cm^2 medium cylindrical hydroponic channels (Kumar pipes, Pvt Ltd., Nellore, Andhra Pradesh) and 38-mm drain pipe and with a 6% slope of PVC pipes to allow NS return to the tank. Each seedling was given a distance of 20 cm between them.

After the process of the seeds germinating into young seedlings, thirty *S. oleracea* seedlings were transplanted into the NFT system. Since plants need a constant supply of nutrients, the pump was left on constantly from the day after transplant (DAT) until the completion of the experiment. This was done from dawn to night because the pump was switched on continually.[9, 10] In order to ensure that the plants received sufficient amounts of water and nutrients, the pump was switched off for one hour in the morning and one hour in the evening, or for intervals of up to five minutes.[11]

Water- pH, EC and TDS

The distilled water was with pH -5.9, EC -100 S/cm, and TDS -50 ppm. To keep the chelates in a stable state, pH ~ 4 was maintained using hydrochloric acid (HCl) or sodium hydroxide (NaOH) 1 N solution, with daily replenishment[12] and weekly replacement to prevent nutrient concentration changes.

Parameters evaluated

The EC, pH, TDS, and temperature of the NS from NFT tanks were measured every day. To keep them steady in NS, we added R.O water at the end of the first, second, and third weeks and nutrient stocks (A & B) after the first and third weeks, respectively. Since nutrient absorption rates drop out precipitously beyond 30°C, the NS tank's temperature was monitored regularly and kept in that range.

We measured the root length, shoot height and leaf count on days 7, 14, and 21 post-transplants. The growth performance of the plant was compared to the nutrient solution (NS) present in the tank over a three-week period, with measurements taken daily from the first week (DAT 1) to the third week (DAT 21). Parameters measured included electrical conductivity (EC), pH, total dissolved solids (TDS), and temperature of nutrient solution. Whereas climatic parameters such as temperature and humidity were noted.

RESULTS

Growth parameters of *S. oleraceae*

At days after transplant (DAT) 7, 14, and 21, we recorded shoot length, root length, leaf count, node count, and shoot-to-root ratio for *Spinacia oleracea*. At each juncture, we determined each metric's mean and standard deviation. The average length of *S. oleracea* shoots grew from 3.15 ± 0.5 cm on DAT 7 to 12.35 ± 1.0 cm on DAT 21. There was also a consistent growth in root length, which went from an average of 0.65 ± 0.1 cm (DAT 7) to an average of 1.77 ± 0.1 cm (DAT 21). Over the course of the three weeks, the average number of leaves per stem rose from 5 ± 0.4 on DAT 7 of the first week to 34 ± 0.7 on DAT 21 of the third week. The ratio of shoots to roots also changed with time, from a mean of 4.8 on DAT 7 to 7.2 on DAT 21 (Table 1) indicating that the shoot growth is relatively faster than the root growth as the plant matures. The data indicates that the spinach plants have grown in every measurable way over the past 21 days (Fig. 1).

Table 1: Biometric parameters of *Spinacia oleracea*.

	DAT 7	DAT 14	DAT 21
Shoot Length (cm) (Mean ± S.D)	3.15 ± 0.5	7.65 ± 0.7	12.35 ± 1.0
Root Length (cm) (Mean ± S.D)	0.65 ± 0.1	1.14 ± 0.1	1.77 ± 0.1
No. of Leaves (Mean ± S.D)	5 ± 0.4	14 ± 1.0	34 ± 0.7
Shoot-to-root ratio	4.8	6.7	7.2

Note: Number of replicates maintained (n=30)

Fig. 1: Spinach plant grown in NFT on (A) DAT 7, (B) DAT 14, and (C) DAT 21.

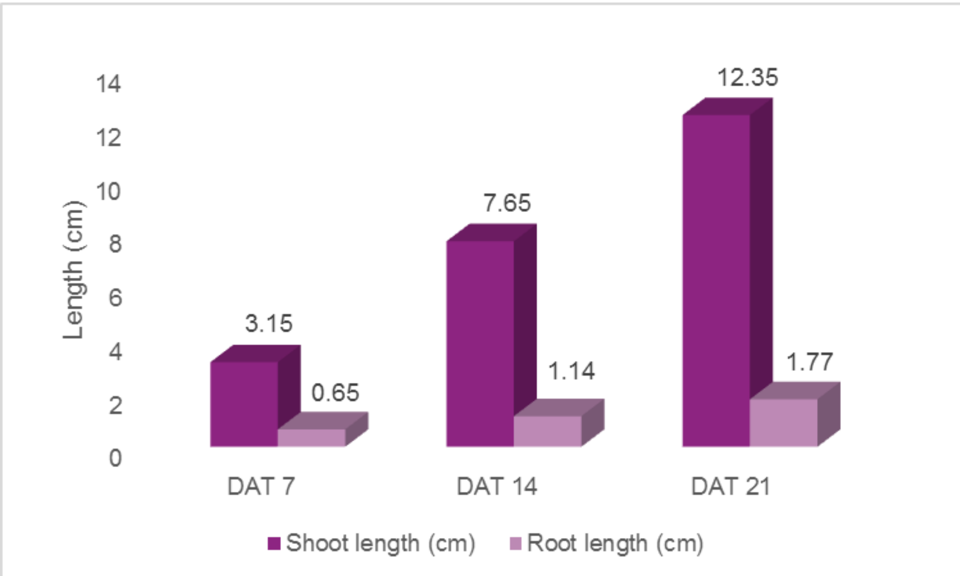


Fig. 2: Comparative analysis of shoot and root growth dynamics on DAT 7, DAT 14, and DAT 21.

Temperature and humidity

During the three weeks, environmental factors also exhibited significant variation. The temperature fluctuates slightly over the course of 21 days, ranging from 27°C to 32.6°C. On DAT 11 the highest temperature is recorded, while on DAT 2 the lowest. Additionally, humidity levels range from 62% to 89% over the course of twenty-one days (Table 2).

Table 2: Climatic parameters (temperature and humidity) readings by DAT.

DAT	Temperature (°C)	Humidity (%)
1	28.9	88
2	27.0	89
3	29.1	85
4	29.7	84
5	30.0	74
6	30.5	76
7	29.9	82
8	30.6	77
9	30.0	73
10	30.2	70
11	32.6	62
12	31.0	64
13	31.0	64
14	31.9	63
15	28.5	87
16	29.7	85
17	31.6	64
18	31.5	66
19	31.0	68
20	30.8	78
21	30.7	78

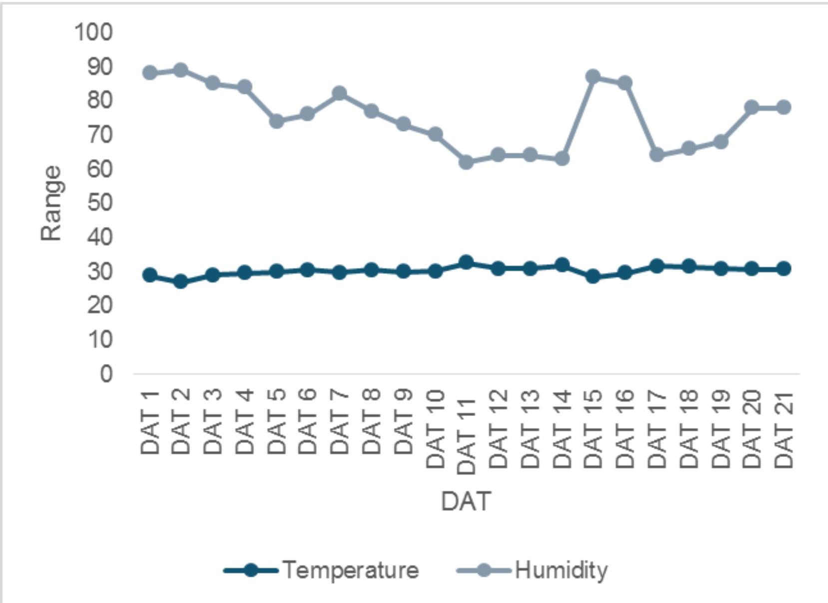


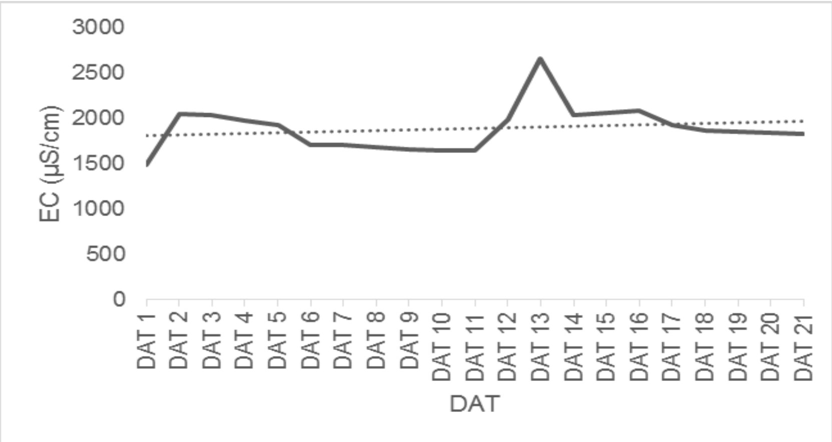
Fig. 3: Analysis of climatic temperature and humidity over the period of DAT (1-21).

Nutrient solution parameters

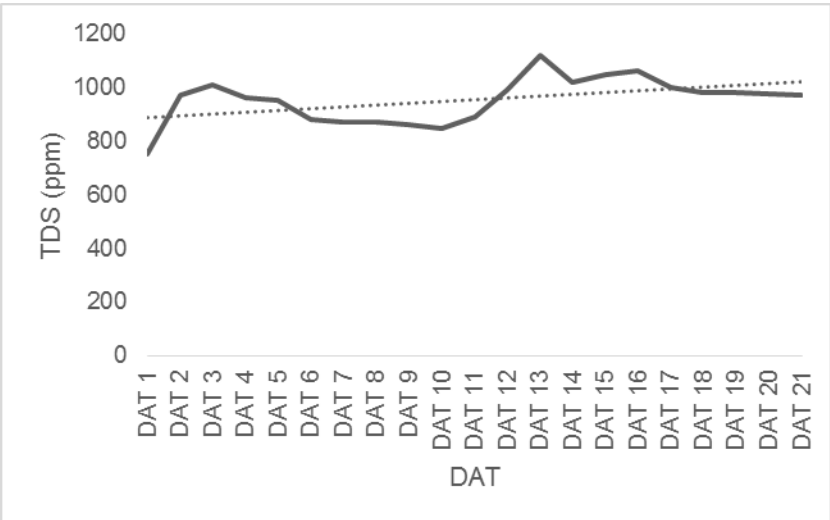
The EC ranged from 1490 to 2660 µS/cm, pH ranged from 3.6 – 5.1 TDS ranged from 750 to 1120 ppm, and temperature ranged from 28.1°C to 30.1°C (Table 3). The values of electrical conductivity (EC), total dissolved solids (TDS) and temperature (Fig. 4 A, B, D) fluctuate over the course of 21 days, whereas the pH remains relatively stable (Fig. 4 C). These parameters indicate the solution's nutrient content and acidity.

Table 3: Physical parameters observed for *Spinacia oleracea* in the nutrientsupplemented water.

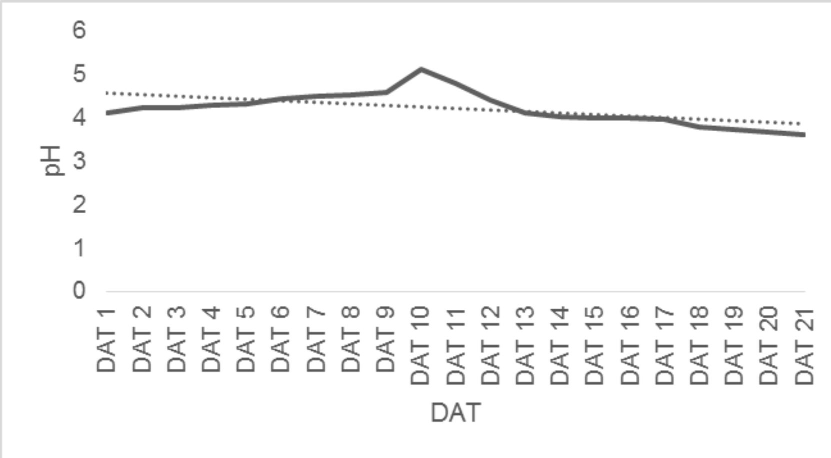
DAT	E.C. (μS/cm)	T.D.S. (ppm)	pH	Temp (°C)
1	1490	750	4.10	28.1
2	2050	970	4.23	28.4
3	2030	1010	4.22	28.3
4	1970	960	4.29	28.4
5	1920	950	4.32	28.2
6	1710	880	4.45	28.5
7	1700	870	4.50	29.2
8	1680	870	4.51	28.9
9	1660	860	4.58	28.2
10	1650	847	5.10	28.1
11	1640	890	4.80	29.0
12	1990	990	4.40	29.5
13	2660	1120	4.10	28.4
14	2040	1020	4.02	28.8
15	2060	1048	4.00	29.0
16	2090	1062	3.98	29.1
17	1930	997	3.97	29.5
18	1862	980	3.80	30.0
19	1857	982	3.72	30.1
20	1835	976	3.68	30.0
21	1832	970	3.62	29.9



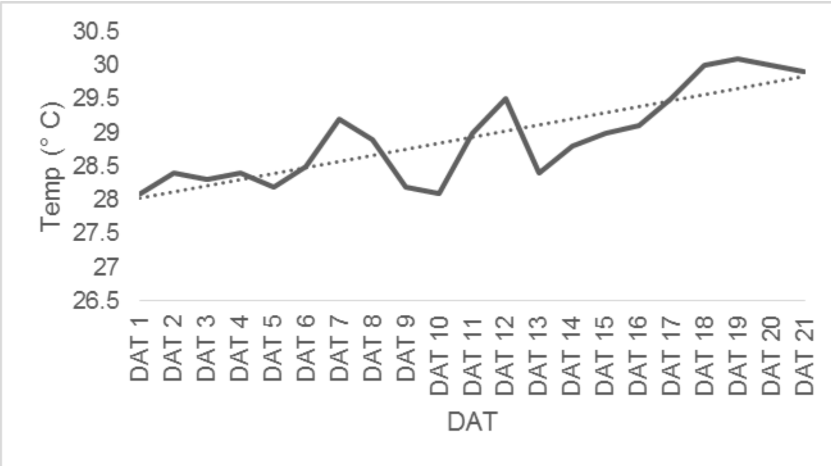
(A)



(B)



(C)



(D)

Fig. 4: Analysis of nutrient solution parameters daily for three weeks (DAT 1-21) (A) Electrical Conductivity (EC), (B) Total Dissolved Solids (TDS), (C) pH and (D) Temperature.

Integrated analysis for growth trends

DAT 1-7: The development process has just started, and the measurements of pH, EC, and TDS indicate that the conditions may not be ideal for growth. This might be because the plants are experiencing early stress or are still adapting to their new environment.

DAT 8-14: All parameters have reached a stable state, and the plant is exhibiting a growth reaction to the changing environment, particularly in the roots. This enhanced growth in the roots may be a result of their vigorous search for nutrients after the previous fluctuating conditions.

DAT 15-21: The pH, EC, and TDS levels have stabilized, and the temperatures are favourable. These circumstances are very conducive to growth, as seen by the significant rise of both shoot and root lengths.

DISCUSSION

In the recent years hydroponics has become an effective and sustainable way in the modern agriculture which got a wide range of acceptance in meeting the huge demand for qualitative and healthy food in emerging economies.[13] The increasing sophistication of mathematical models utilised in hardware software interfacing, artificial intelligence, and adaptive data analysis has enabled the hydroponics to implement a more comprehensive level of automation through versatile design and control strategies.[14] Furthermore, hydroponic farming permits continuous crop cultivation throughout year irrespective of climate changes, which is not achievable with the conventional agricultural practices.[3,8] Several studies along with the current study have demonstrated the potential of spinach cultivation using hydroponics where the plants grown had significantly higher yields and better quality.

The current study investigates both the climatic and physical parameters of the nutrient solution for the growth of spinach in NFT. The pH stability seen in the early days indicates a state of balance, during which the pH is unaffected by other variables, or the effects of treatment have not yet been apparent. The following decrease may indicate that the system's ability to resist changes in pH is restoring the pH to its initial value. The significant growth of spinach shoot and root length by DAT 21 could indicate that the pH returned to a more favourable range, promoting better nutrient absorption. Whereas the initial decrease in electrical conductivity

(EC) may suggest the presence of diluted or degraded soluble salts. Probably, the variations seen in Total Dissolved Solids (TDS) might arise from many sources, such as the introduction of soluble chemicals into the system or the dilution of the dissolved solids. Both the electrical conductivity (EC) and total dissolved solids (TDS) levels showed a rise on DAT 11, indicating a greater presence of ions and solid particles in the solution. This observation may be indicative of enhanced nutritional availability. Although a greater total dissolved solids (TDS) level might signal the presence of more nutrients, too high concentrations can also result in osmotic stress, which may hinder development. Nevertheless, the significant growth in both root and shoot length seen by DAT 21 indicates that the spinach plants were able to efficiently use these nutrients without experiencing any detrimental stress. This is likely due to the fact that the electrical conductivity (EC) and total dissolved solids (TDS) level returned to a more moderate range. The temperature has the ability to impact many measures including TDS, EC, and pH due to its effect on solubility and reaction rates. Elevated temperatures may lead to an increase in Total Dissolved Solids (TDS) and Electrical Conductivity (EC) as a result of enhanced solubility of solids and ions. However, the temperature of the nutritional solution in the present study varies within a range of 3 degrees. This phenomenon may be attributed to inherent fluctuations in daily temperatures. Despite fluctuations in climatic and nutrient parameters, the plants have successfully adapted to these conditions.

CONCLUSION

The concurrent increase and decrease of the parameters suggest a mutually reinforcing impact, necessitating a comprehensive strategy for effective management. If an intervention increases both TDS (Total Dissolved Solids) and EC (Electrical Conductivity), but the pH stays constant, it is possible that the treatment is adding neutral salts. On the other hand, if the pH varies along with the EC and TDS, it is possible that the treatment is adding ions that are either acidic or basic. The dotted lines in the graphs (EC, TDS, pH and temperature) indicate future projections derived from the observed patterns. This prognostic data might be crucial for strategizing further interventions, comprehending the patterns of the system, and reducing any possible detrimental consequences resulting from elevated electrical conductivity, total dissolved solids, or improper pH levels. To summarize, the present study provides useful insights for commercial cultivators for higher yields, improved quality, and enhanced sustainability on the large-scale production of spinach using NFT hydroponics.

REFERENCES

1. Miano, Tahseen Fatima. "Nutritional value of *Spinacia oleraecea* spinach-an overview." International Journal of Life sciences and review, 2016; 2.12: 172-174.
2. Jones Jr, J. Benton. Hydroponics: a practical guide for the soilless grower. CRC press, 2016.
3. Jan, Seerat, et al. "Hydroponics–A review." International Journal of Current Microbiology and Applied Sciences, 2020; 9.8: 1779-1787.
4. Lages Barbosa, Guilherme, et al. "Comparison of land, water, and energy requirements of lettuce grown using hydroponic vs. conventional agricultural methods." International journal of environmental research and public health, 2015; 12.6: 6879-6891.
5. Firdes, U. L. A. S., et al. "Leaf physiological and root morphological responses of some fruit bearing vegetables as affected by different rates of nitrogen." International Journal of Agricultural and Natural Sciences, 2018; 1.1: 19-24.
6. Agarwal, Ankur. "Comparative Performance of Spinach (*Spinacia Oleracea*) as Affected by Growing Media Hydroponics vs. Soil." Research & Reviews: Journal of Botanical Sciences, 2021.
7. Syed, Ain-ul-Abad, et al. "Comparative Assessment of Hydroponic and Geoponic Cultivation Systems for Sustainable Spinach Cultivation." Pakistan Journal of Agricultural Research, 2021; 34.4.
8. Vox, Giuliano, et al. "Sustainable greenhouse systems." Sustainable agriculture: technology, planning and management, 2010; 14.
9. Graves, Chris J. "The nutrient film technique." Horticultural reviews, 1983; 5: 1-44.
10. Graves, C. J., and R. G. Hurd. "Intermittent solution circulation in the nutrient film technique." Nutrient Film Technique and Substrates, XXI IHC, 1982; 133: 47-52.
11. Zanella, Fábio, et al. "Crescimento de alface hidropônica sob diferentes intervalos de irrigação." Ciência e Agrotecnologia, 2008; 32: 366-370.
12. Furlani, Pedro Roberto, et al. Cultivo hidropônico de plantas. Vol. 180. Campinas: IAC, 1999.
13. Taylor, Robert, et al. "Making global cities sustainable: Urban rooftop hydroponics for diversified agriculture in emerging economies." OIDA International Journal of Sustainable Development, 2012; 5.7: 11-28.
14. Srivani, P., and S. H. Manjula. "A controlled environment agriculture with hydroponics: variants, parameters, methodologies and challenges for smart farming." 2019 Fifteenth International Conference on Information Processing (ICINPRO). IEEE, 2019.