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Comparative Analysis of Growth Parameters in Hydroponic and Soil-Grown Systems of *Ocimum basilicum* L. (Basil)

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ABSTRACT

This study's primary objective was to compare basil growth (Ocimum basilicum L.) in three different systems: soil-based, EBB & Flow, and Nutrient Film technique (NFT). During the 45-day growth period, the following factors were examined: plant height, root length, leaf length, leaf breadth, stem diameter, number of leaves, water quality parameters, soil macro- and micronutrients, and nutrient uptake. The findings showed that, for NFT, EBB hydroponics, and soil-based systems, the plant heights of basil plants at the end of the growth period were 40 ± 3.10, 30.80 ± 2.82, and 28.50 ± 3.17 cm, respectively. The NFT hydroponics system yielded the maximum root height measurement of 34 ± 3.92cm for basil plants. After the trial, the amount of nutrients absorbed from hydroponically grown water ranged from 70 to 87%, indicating the phytoremediation of wastewater. According to the findings, the NFT hydroponic system significantly outperformed the EBB and soil-based methods for growing basil plants regarding growth characteristics. The study's findings indicate that the hydroponic system is the most effective technique for growing basil.

Keywords: *Basil; NFT, EBB & Flow, Hydroponics, Soil based system*

1. Introduction

Climate change, growing urbanization, water scarcity, and shrinking arable land all put pressure on output from agriculture. The current estimate is that by 2050, there will be 10 billion people on the planet. According to [1], there is also an anticipated rise in the city's living rate from 50 to 70% in the 2030s, conventional agriculture suffers from the growing consequences of climate change, including drought, salinity, floods, and extreme temperature swings. Soilless culture can mitigate these effects and guarantee long-term, sustainable food security. The principal application of soilless culture systems is in controlled environments, such as greenhouses or plant factories. These systems are beneficial in closed systems with a recirculating water/nutrient solution that collects drain water and stores it for later use [2]. According to [3-4] the hydroponic system, also known as the soilless culture system, is the process of cultivating plants without the need for a substrate or soil, usually in combination with a nutrient solution. According to [5] hydroponics involves submerging the plant roots in an aerated nutrient solution. [6] the solution consists of water and fertilizers carefully dosed to produce the right concentration of macro- and micro-elements required for plant growth. The reduced planting area is efficiently utilized in hydroponic systems. It hence takes less water to operate. The system in large-scale cultivation runs in a closed circuit, with regular pumping, recycling, and renewal of the nutrient solution. To continuously monitor the pH and electro-conductivity (EC) of the nutrient solution, recirculation enables aeration [7]. Plants grown in a hydroponic system receive nutrients in water without needing soil. In hydroponic farming, the minerals are infused directly into the water where the plants grow, negating the requirement for the soil employed in traditional agriculture as a substrate for incorporating water and minerals. They are controlling reusable water after correction, which is more efficient.

It reduces the need for pesticides. Numerous crops, including ornamentals, seasonal flowers, cereal crops, radishes, beets, carrots, and potatoes, can be grown on inert supporting material rather than soil [8]. Growing for food, medicine, and cosmetics, basil (*Ocimum basilicum L.*) is a significant plant that contains flavonoids, polyphenols, phenolics, and essential oils. The basil plant, which belongs to the Lamiaceae family and genus Ocimum, is one of the aromatic plants whose consumption gradually rises. It typically grows in tropical and subtropical climates and is a typical fresh vegetable or spice in human diets [9]. Its potent and distinct scent makes it stand out in meat, vegetables, salad, sauce, herbal tea, and other culinary applications. However, because this plant is not only aromatic but also medicinal and frequently utilized in medical treatments, its value has expanded beyond its original culinary application [10].

Most commonly employed in food production, Ocimum basilicum, or basil, is a highly prized culinary plant [11]. Farmers also grow basil quite frequently nematocidal, antibacterial, fungistatic, and insecticidal activities are just a few of basil's pathogen-killing or repelling qualities [12]. Given these advantages and impacts, basil finds various intriguing applications in the culinary, fragrance, traditional medical, and pharmaceutical industries. One of the most popular plants cultivated under aquaponics, or more precisely linked to aquaponic conditions, is *Oryza basilicum* [13]. Basil leaves acquire a unique and recognizable aroma thanks to unusual oil glands, making it a highly beneficial herb [14]. Thus, practically all nations and cultures utilize it both fresh and dry. Both soil and soilless cultures are appropriate for basil [15]. Hydroponic basil cultivation is well-established [16]. Basil grows well in hydroponic systems because of its excellent growth potential. Producers that use hydroponics and aquaponics have a very high demand for basil. According to studies, basil is the most popular herb for various hydroponics and aquaponics experiments because of its qualities [17-18].

According to [19] basil produces 1.8 kg per meter square when grown aquaponically but only 0.6 kg when grown in soil. Consequently, hydroponic farming is believed to be more ecologically friendly and efficient than soil farming [20]. Due to its great value as a cash crop, basil is one of the top concerns for farmers worldwide [21].

One of the most complex and abundant methods of growing basil is through the soil system (*O. basilicum*) [22] Rich soil with the ideal pH balance for basil growth is perfect for basil plants to flourish. Any farmer may grow high-quality basil with these three requirements: a flawless drainage system, soil with the correct pH, and a location receiving six to eight hours of sunlight daily. In essence, basil is a tropical herb that grows readily in soil that is both damp and rich in nutrients [23]. Basil may be produced hydroponically, which requires less water and no soil while producing a high-quality crop output [24]. This method is environmentally benign. Sudden changes in the climate and other environmental changes do not affect the crops grown using a hydroponic system [25]. System maintenance and appropriate inspections help to preserve quality [26]. Prior research revealed that basil is one of the most often utilized plants in the kitchen and various other business sectors due to its many qualities and attributes [27-30]. This study aimed to compare the effectiveness of soil and hydroponic systems with an emphasis on the macro- and micronutrient levels in basil plants as well as plant growth characteristics. To put it another way, this study aims to determine and comprehend how basil grown in aquaponic, and soil systems differ from one another.

2. Materials and Methods

During the 45-day study period, three samples of basil plants (NFT, EBB, and soil-based system) were collected for chemical analysis and growth assessment. Measurements included plant height, root length, leaf breadth, leaf length, stem diameter, and number of leaves per plant [31]. Harvesting basil was placed 45 days after seeding. In every harvesting cycle, a group of plants was chosen randomly and harvested. We measured the length of the shoots, roots, and average number of leaves per plant to assess the characteristics of each basil harvest. The plant height measurements, which are given in centimetres, were taken from the soil level to the tip of the shoot. The most extended plant root's length was measured in centimetres, starting at the first cotyledonary node and ending at the tip. The number of leaves per plant is the total number of wholly formed leaves counted and expressed. Each plant's total leaf area was determined in centimetres squared.

After digestion, the total content of macro components was assessed [32]. [33] used Kjeldahl digestion procedures to estimate the nitrogen content. Phosphorus (P) was measured using a UV spectrophotometer, whereas potassium, calcium, and magnesium were measured using a flame photometer [34]. Using the standard protocols from the APHA 23rd edition, water samples were collected at the inlet and outlet of the units of the hydroponic system to measure pH, EC, DO, nitrogen (N), ammonical nitrogen, sulphates, phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), boron (B), iron (Fe), zinc (Zn), cobalt (Co), and nickel (Ni) throughout the one-year experimental period. Similar to this, conventional techniques outlined in ASTM 2006 were used to monitor the pH, EC, Organic Carbon (OC), and Nutrients such as N, P, K, Ca, Mg, Na, B, S, Fe, Zn, Cu, Mn, Cd, Co, and Ni in soils.

2.1 Determination of micro and macro elements in hydroponics and soil-based systems

Macro- and microelement studies were performed to determine how various treatments affected basil plants' nutrition in soil-based and hydroponic systems. An atomic absorption spectrometer was used to analyse N, P, K, Ca, Mg, Na, B, S, Fe, Zn, Cu, Mn, Cd, Co, and Ni. However, spectrophotometers were used to analyse P, S, and N for the Na, K, Ca, and Mg microelements, respectively [35].

3. Results and Discussion

3.1 Plant growth comparison of Basil in NFT, EBB & Flow and Soil based system

The growth and morphology of basil plants cultivated in two different hydroponic systems—the Nutrient Film Technique (NFT) and EBB & Flow systems—as well as conventional soil systems are examined in this study. Figure 1 shows how the growth and morphological traits of basil grown in soil-based, hydroponic NFT, and EBB & Flow systems differ. The study looks at various plant growth metrics, including root length, stem diameter, leaf breadth, leaf length, and number of leaves per plant. The basil plants displayed significant property differences when grown in the NFT system in various environmental conditions (Figure 1).

The basil plants grown under the NFT system had the maximum plant height (40.4±3.10cm), while those grown using the EBB & Flow system had the lowest (30.80±2.82cm). Plants grown using soil-based techniques had the lowest average height (28.50±3.17cm).

Soil-based systems had the fewest leaves per plant (12±2), while the NFT system had the highest number of leaves per plant (15±2). The breadth of the basil leaves grown in the NFT system (8.02±0.74cm) was significantly bigger ($P<0.05$) than the leaves of crops grown in soil-based systems (1.12±0.11cm2) and EBB & Flow systems (1.21±0.15cm2) (Figure 2). It might be feasible because more leaves produce more photosynthetic products and a higher photosynthetic reaction. The NFT system yielded the most significant values (7.02±0.91cm and 34±3.92cm) for the basil plants' stem diameter and root length. The EBB & Flow system (6.80±0.69cm and 28.3±3.92cm) and soil-based systems (6.65±1.03cm and 25.3±4.85 cm) had the lowest values ($P<0.05$).

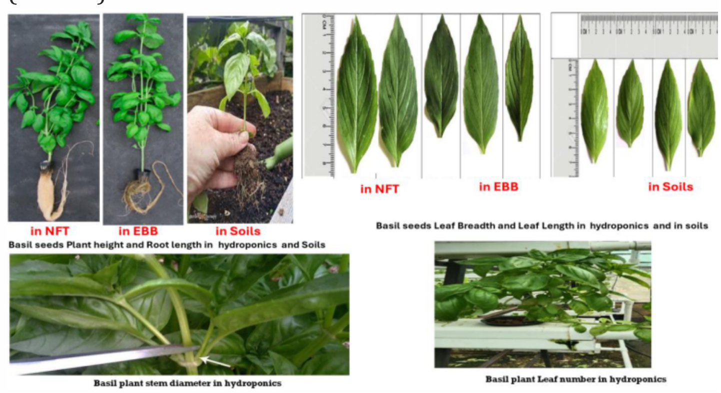

Figure 1: Comparison of plant growth parameters in hydroponics and soil-based systems

The plants in the soil and hydroponic systems showed a growth spurt as they grew older, beginning to reach their maximum height at forty-five days. On the other hand, the EBB hydroponic-grown plants showed 34cm, and the soil-based system showed 30cm, a reduced height compared to the NFT hydroponic system at 45 days (48cm). All plant growth-related indicators showed a similar pattern (Table 1). In both systems, the length of the root rose with age. Compared to plants cultivated hydroponically, the root length in the soil system shrank (Table 1). In a hydroponic system, the average root length of basil plants was 34 cm, while, after 45 days, the average root length of plants produced in a soil system was 25.30 cm.

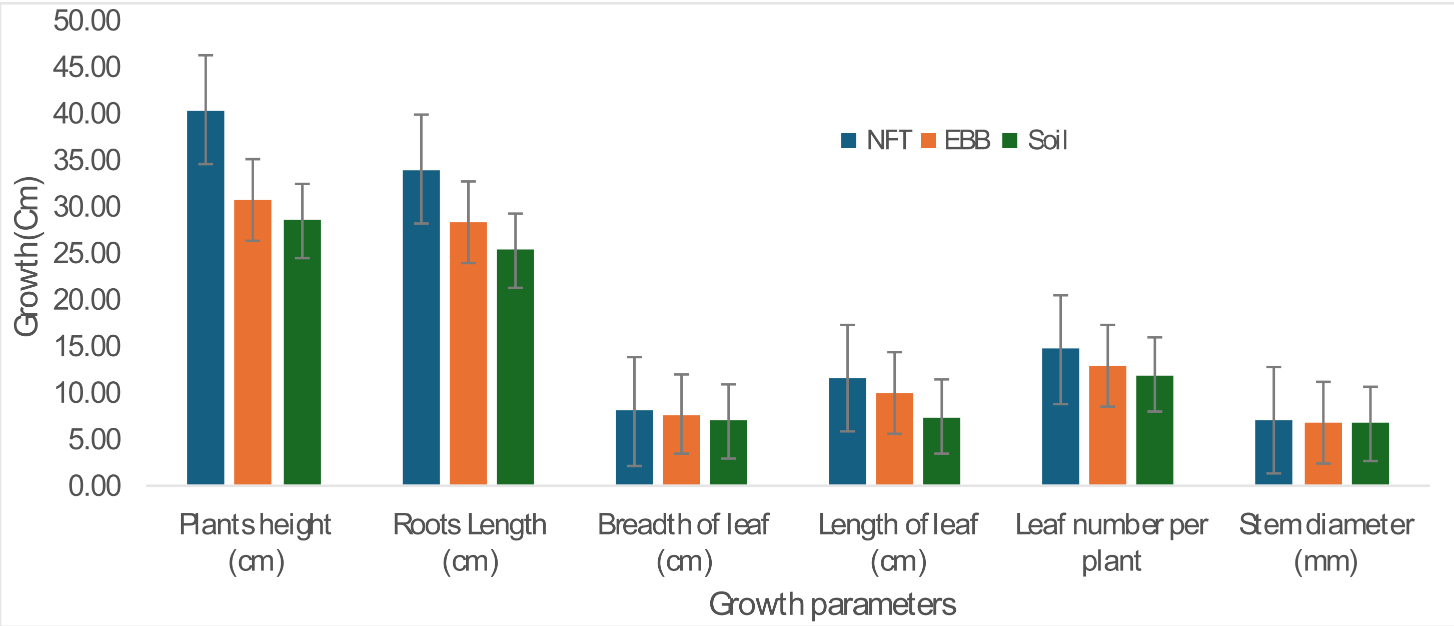

Figure 2: Comparison of plant growth parameters in hydroponics and soil-based systems

The findings show that the NFT hydroponic system's all-basil plant growth parameters were considerably more significant than those of the soil-based and EBB hydroponic systems. These findings were consistent with those of [37]. They discovered that the height of the plants cultivated hydroponically was equal to that of the plants grown using other traditional techniques. Compared to soil, this previous system accelerates the roots' absorption of critically needed nutrients and oxygen, increasing metabolism and development rate [38]. The results of this study were in line with those of [39]. Moreover, numerous studies have demonstrated that hydroponic systems increase plant growth rates by encouraging root aeration because the roots are grown wholly suspended in the atmosphere, providing the plant's stem and root systems with 100% of the oxygen that is available to them [40]. These findings corroborate those of [41] who observed that the aeroponic system's plant root length, area, and volume far outperformed those of the hydroponic and substrate systems.

3.2 Water Parameters

Table 1: The average water parameters under hydroponic system

Parameter	Inlet water				Outlet water				% of nutrient uptake
	Min	Max	Mean	Std	Min	Max	Mean	Std	
pH	6.23	7.25	6.70	0.30	6.44	7.56	7.14	0.30	6.55
EC	1818	1890	1854	23.30	185	220	201	10.25	89.17
DO	6.20	6.85	6.42	0.18	1.98	2.45	2.11	0.13	67.16
Nitrates	13.18	14.32	13.93	0.34	0.54	1.88	0.94	0.34	93.24
Ammonical Nitrogen	118	188	144	24.73	12	18	15	2.34	89.61
Sulphates	26	34	30.83	2.48	4.12	7.58	5.62	1.11	81.78
Phosphates	14	24	19.67	3.17	0.95	3.12	1.76	0.63	91.07

In the hydroponic system, there were fluctuations in the pH, electrical conductivity (EC), dissolved oxygen, ammonical nitrogen, nitrates, phosphates, and sulphates at various intervals. It is well known that nitrate and nitrite levels rose in response to an increase in ammonia. Throughout the trial, the pH level also showed a range of levels.

The measured dissolved oxygen values ranged from 6.85 mg/l at the highest to 6.20 mg/l at the lowest. 7.25, the pH level was the highest recorded, and at 6.23, the lowest. The variation throughout the 45-day observation led to the average water parameters of EC. The highest measured temperature was 1890µs/cm. Ammonia concentrations were noted to be highest 188 mg/l and lowest 118 mg/l (Table 1).

3.3 Macronutrients and Micronutrients

The components were examined solely at the conclusion of the 45-day study period. The hydroponic system exhibited higher amounts of macro- and micronutrients than the conventional soil-based system, as seen in Table 2.

Table 2: Macronutrients (%) and micronutrients (mg/kg) in basil grown hydroponics water.

Parameters	Inlet water				Outlet water				% of nutrient uptake
	Min	Max	Mean	Std	Mean	Std	Min	Max	
Ca	50.66	87.95	78.86	11.80	16.33	3.50	12.00	22.00	79.06
Mg	23.73	41.77	36.51	5.18	7.58	1.68	3.00	9.00	79.30
K	13.83	20.09	17.42	1.65	4.08	1.16	2.00	6.00	76.35
Na	71.87	128.00	112.94	17.37	17.67	2.81	12.00	22.00	83.95
S	4.33	8.05	6.88	1.04	1.98	0.27	1.58	2.56	70.38
B	0.06	0.11	0.09	0.02	0.02	0.005	0.01	0.03	76.11
Fe	0.11	0.21	0.1609	0.0292	0.0192	0.009	0.00	0.03	87.56
Zn	0.012	0.060	0.030	0.014	0.0043	0.0027	0.002	0.01	83.79
Co	0.045	0.065	0.0551	0.0065	0.0115	0.0024	0.008	0.016	79.05
Ni	0.0025	0.0033	0.0026	0.0002	0.002	0.0004	0.002	0.002	0.00

3.4 Nutrients uptake

Table 1 presents a comparison of the physicochemical characteristics and their uptake of basil plants produced in three different systems throughout the study period: NFT hydroponic, EBB hydroponic, and soil based. The findings show that the basil plants in the NFT hydroponic system absorbed more nitrates, ammonical nitrogen, sulphates, and phosphates than those in the EBB hydroponic and soil-based systems. It was evident that, under hydroponics, the nitrogen intake of basil plants was 93%, ammoniacal nitrogen 89.61%, sulphates 81.78% and phosphates 91.07%.

After 45 days of transplanting, the micronutrient uptake values for potassium (76.35%), calcium 79.06%, magnesium 79.30%, sodium 83.95%, boron (76.11%), iron 87.56%, zinc 83.79%, and cobalt 79.05% were recorded by basil plants. These results were consistent with those reported by Li Q et al. (2018), who found that hydroponic and aeroponic systems had higher nutrient uptake than substrate-cultivated systems.

3.5 Nutrients in hydroponics water and soil

Table 3: Nutrients concentration of hydroponics water

Parameter	Min	Maximum	Mean	Std
pH	7.09	8.65	8.01	0.563721
EC (ms)	0.11	0.18	0.14	0.03
OC	0.05	1.34	0.52	0.54
Total-N	362	1470	782	432
Total-P	175	645	285	126
Total-K	393	2236	795	659
Total-Ca	1908	20638	14599	6493
Total-Mg	1142	2700	1771	685
Total-Na	234	423	334	68
Total-B	24	120	55	33
Total-S	64	499	222	196
Total-Fe	8874	16533	10793	2722
Total-Zn	8.39	38	17	10
Total-Cu	6.67	14.59	10.21	3.07
Total-Mn	160	328	248	58
Total-Cd	0.09	0.73	0.33	0.21
Total-Co	6.67	12.18	8.13	1.84
Total-Ni	8.19	29.03	12.73	7.43

The soil samples' pH for cultivating basil ranged from 7.09 to 8.65, with an average value of 8.01±0.56. The range of electrical conductivity and organic carbon (OC) levels was between 0.11 and 0.18Ms/cm and 0.05 and 1.34%, respectively. The mean values were 0.14±0.03Ms/cm for electrical conductivity and 0.54±0.05% for organic carbon. Basil achieves best growth when cultivated in soil with a pH of 6.5 to 8 and an electrical conductivity (EC) range between 1.8 and 2.3. It is essential to mention that soil organic carbon is generally present in greater amounts in the top layer of soil, known as topsoil. Highland soils often have an organic carbon concentration ranging from 0.5% to 3.0%. The average concentrations of nitrogen (N), phosphorus (P), and potassium (K) in the soil were 782±32, 285±12, and 795±59 mg/kg, respectively. These amounts ranged from 362 to 1470, 175 to 645, and 393 to 2236 mg/kg. Table 2 presents the additional nutritional information.

The soil samples' pH varied between 7.09 and 8.65 for cultivating basil, with an average value of 8.01±0.56. The electrical conductivity ranged from 0.11 to 0.18 Ms/cm, whereas the organic carbon (OC) values ranged from 0.05 to 1.34%. The average electrical conductivity and organic carbon values were 0.14±0.03Ms/cm and 0.54±0.05%, respectively. Basil thrives when grown in soil with a pH of 6.5 to 8 and an electrical conductivity (EC) between 1.8 and 2.3. It is crucial to note that soil organic carbon is typically found in higher concentrations in the uppermost layer of soil, referred to as topsoil. The organic carbon concentration in Highland soils generally ranges from 0.5% to 3.0%. The mean contents of nitrogen (N), phosphorus (P), and potassium (K) in the soil were 782±32, 285±12, and 795±59 mg/kg, respectively. The quantities varied between 362 and 1470 mg/kg, 175 and 645 mg/kg, and 393 and 2236 mg/kg. Table 2 displays supplementary nutritional data.

4. Discussion

Medicinal uses for the herb basil, or *Ocimum basilicum L.*, include treating kidney problems, coughing, and headaches. The plant's numerous essential chemical components are the foundation for these therapeutic qualities. According to [46], basil is a good source of the antioxidant vitamins E, A, and C. These antioxidant-rich substances contribute to improving human health.

4.1 Plant Growth Parameters

First and foremost, the basil plant's overall height increased as it grew older. Examining the soil and hydroponic systems served as the foundation for this. In 45 days, the plant managed to grow to its full height. The plants grown using the soil-based method produced results very different from those of the hydroponic system. When compared to a soil-based system, the root length of the plants in both NFT and EBB systems revealed comparable results in terms of height.

The current study's results contradict a prior survey by [47] which reported a decrease in basil growth in various culture conditions with catfish (*Clarias gariepinus*) in decoupled aquaponics. In that study, plant height was higher than in conventional basil cultivation. Our findings are consistent with previous research by [48-49], which found that inoculating basil with *Azospirillum brasilense* greatly enhanced its growth and yield in an aquaponics system. When comparing the vegetative growth, eco-physiological traits, and mineral nutrient content of basil plants irrigated with various hydroponic: aquaponic solutions, [50] found a decrease in vegetative growth. According to [51] fresh herbage output and basil leaf area decoupled hydroponics, while the plants in hydroponics demonstrated strong growth performance.

4.2 Macroelements and Microelements

The macro- and micronutrients in basil plants analysed at 45 days in soil and hydroponic systems served as the basis for the results. The primary macronutrients found in basil plants are calcium, magnesium, phosphorus, potassium, and nitrogen. According to the analysis, the nitrogen concentrations of the hydroponic system were higher than those of the soil system. Phosphorus, potassium, and calcium components displayed outcomes comparable to those of nitrogen. On the other hand, after 45 days, the macronutrients of sulphur were present in more significant or similar amounts in the soil and hydroponic systems.

Plants growing in soil have a lower nutritional content. The basil plant grows more quickly in aquaponics systems because the plants have access to more nutrients. Aquaponics systems use recirculating water beds. In an aquaponics system, fish waste often provides vital nutrients like calcium, magnesium, potassium, and nitrogen that plants need to develop [52].

Recent evidence indicates that there needs to be more knowledge regarding aquaponic nutrient manipulation. As major nutrient elements to supplement the aquaponic solution, potassium, and iron can be added to the system as foliar sprays of potassium hydroxide and iron chelates [53].

4.3 Water Quality Parameters

Examining many internal observations on the hydroponic system of basil plants provides the basis for the results of the water quality parameters. Days 1 through 40 of the analysis saw constant temperature fluctuations between 24 and 25^{0}C. The dissolved oxygen level was considered the greatest on day ten of the analysis.

According to research, the proper pH ranges for tilapia fish are 6–9; for plants, they are 5.5–6; and for nitrifying bacteria, they are 7–8. Therefore, we can determine that pH 7 is an excellent and appropriate compromise for hydroponics [54]. According to this study, the daily nutrient release from the fish feed was the primary cause of the EC in aquaponics. In any growth system, 20–25°C is the recommended water temperature for basil [55].

5. Conclusions

The primary objective of this experiment was to assess and contrast the development and quality of basil plants using several production methods, namely NFT hydroponic, EBB hydroponic, and soil-based systems. The study focused on analysing plant growth metrics and the presence of macro and micronutrients in both water and soil. Additionally, the study examined the plants' process of nutrient uptake. Furthermore, the amounts of micro and macronutrients displayed diverse reactions when cultivated hydroponically. The findings of this study indicate that basil may be grown successfully in both hydroponic and soil systems. However, the adoption of a hydroponic system can enhance both the amount and quality of the crop. The growth parameters of basil in a hydroponic system exhibited a substantial increase compared to conventional soil systems.

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